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Bureau of Mines Information Circular/1987

Bureau of Mines Cost Estimating System Handbook

(In Two Parts)
2. Mineral Processing

Compiled by Staff, Bureau of Mines

UNITED STATES DEPARTMENT OF THE INTERIOR

Information Circular 9143

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FOREWORD

Need for the Handbook

A computerized mineral inventory system to help the United States Government appraise critical shortages of materials has been eatablished. This involves evaluation of mineral deposits using the Bureau of Mines Minerals Availability System (MAS). The MAS is concerned with costing mineral occurrences where it is unknown, if they can be mined and/or processed at a profit. Therefore a consistent functional method of costing both mining and mineral processing is a requirement of the financial analysis phase of MAS. The objective of this handbook is to develope a manual method for preparation of feasibility type estimates for capital and operating costs of mining and primary mineral processing of various types of mineral occurrences using state-of-the-art technology.

Use of the Handbook

This handbook has been developed for a user with knowledge and experience in both mining and estimating procedures. The user should not use this handbook to try to determine the cost of any single component of a mining or mineral processing system. The combination of components will produce a reliable feasibility type estimate which should fall within 25 percent of expected actual cost. The estimated values from the use of the handbook are not intended to duplicate any specific mineral producer's capital or operating costs. Individual component costs may vary.

CONTENTS

CONTENTS--Continued

MINERAL PROCESSING--CAPITAL COSTS--Continued

CONTENTS--Continued

MINERAL PROCESSING--CAPITAL COSTS--Continued

CONTENTS--Continued

MINERAL PROCESSING--OPERATING COSTS

CONTENTS--Continued

MINERAL PROCESSING--OPERATING COSTS--Continued

CONTENTS--Continued

INFRASTRUCTURE--CAPITAL COSTS

INFRASTRUCTURE--OPERATING COSTS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Btu	British thermal unit
Btu/ft^3	British thermal unit per cubic foot
cm	centimeter
cm/yr	centimeter per year
°C	degree Celsius
°F	degree Farenheit
ft	foot
ft^2/st	square foot per short ton
gal	gallon
gal/d	gallon per day
g/mt	gram per metric ton
gpm	gallon per minute
gpm/m^2	gallon per minute per square meter
h	hour
ha	hectare
h/d	hour per day
hp•h/mt	horsepower hour per metric ton
Hz	hertz
in	inch
kg	kilogram
kg/h	kilogram per hour
(kg/h)/cm	kilogram per hour per centimeter
kg/mt	kilogram per metric ton
$(kg/m^2)/h$	kilogram per square meter per hour
kg/m^3	kilogram per cubic meter
km	kilometer
kW	kilowatt
kW•h	kilowatt hour
kW•h/mt	kilowatt hour per metric ton
L	liter
lb	pound
$(lb/ft^2/h)$	per square foot per hour
lb/ft^2	pound per square foot
lb/ft^3	pound per cubic foot
L/min	liter per minute
L/s	liter per second
lb/mt	pound per metric ton
$(L/s)/m^2$	liter per second per square meter
m	meter
m^2	square meter
m^2/mt	square meter per metric ton
$m^2/mtpd$	square meter per metric ton per day
m^3	cubic meter
m^3/d	cubic meter per day
m^3/mt	cubic meter per metric ton
m/min	meter per minute
um	micrometer
mg	milligram
mg/L	milligram per liter
MMBtu/mt	million British thermal units per metric ton
MMmt	million metric tons
mt	metric ton
mtpd	metric ton per day
mtph	metric ton per hour
mt•km	metric ton kilometer
MV•A	megavolt ampere
ppm	part per million
tr oz	troy ounce
yr	year

BUREAU OF MINES COST ESTIMATING SYSTEM HANDBOOK

(In Two Parts)

2. Mineral Processing

Compiled by Staff, Bureau of Mines

ABSTRACT

This Bureau of Mines report and its companion report (Information Circular 9142) have been prepared to assist in the preparation of prefeasibility type estimates for capital and operating costs of beneficiation of various types of mineral occurrences using current technology. The handbook provides a convenient costing procedure based on the summation of the costs for the unit processes required in any particular mining or mineral processing operation.

The costing handbook consists of a series of costing sections, each corresponding to a specific mineral processing unit process. Contained within each section is the methodology to estimate either the capital or operating cost for that unit process. The unit process sections may be used to generate, in January 1984 dollars, costs through the use of either costing curves or formulae representing the prevailing technology.

The mineral processing handbook includes individual cost estimation sections for unit operations associated with comminution, beneficiation, solid-liquid separation, hydrometallurgy, and special applications as well as infrastructure and plant general and administrative costs. When using this system for estimating cost data for a mineral processing facility or for checking or verifying processing costs from an existing facility, a minimum amount of background information is necessary.

INTRODUCTION

The Interior Department's Bureau of mines systematically measures and classifies identified domestic and foreign mineral resources according to their respective extraction technologies, economics, and commercial availability. To this end, the Bureau collects data on major mines and deposits worldwide and uses these data in estimating and monitoring production costs and availabilities for 34 strategic mineral commodities. The estimation of production costs includes such items as capital expenditures and operating costs for mining and mineral processing operations, as well as transportation and infrastructure costs. A consistent method of costing is a requirement for such analysis. The cost estimation system (CES) has proven invaluable to the Bureau's work in this area.

The CES handbook was developed in 1975 to assist in the preparation of prefeasibility type estimates for capital and operating costs of mining and beneficiation of various types of mineral occurrences using current technology. The system provided a convenient costing procedure based on the summation of the costs for the unit processes required in any particular mining or mineral processing operation. This edition of the handbook is essentially a revision of the earlier effort, updated to reflect the costs of technologies employed as of January 1984. To provide continuity, the numbering system used in the original handbook has been retained.

The following are the 34 strategic commodities targeted for coverage by the updated handbook:

Aluminum	Cobalt	Hafnium	Mercury	Rare earths	Titanium
Antimony	Columbium	Iron	Molybdenum	Silver	Tungsten
Asbestos	Copper	Lead	Nickel	Sulfur	Zinc
Barium	Fluorspar	Lithium	Phosphate	Tantalum	Zirconium
Beryllium	Gold	Magnesium	Platinum	Thorium	
Chromium	Graphite	Manganese	Potash	Tin	

The updated edition of the CES handbook consists of this Information Circular (IC) on mineral processing and IC 9142 on surface and underground mining.

EVOLUTION OF CES

The first edition of the Bureau's Capital and Operating Cost Estimating System Handbook was prepared by STRAAM Engineers, Inc., Mining Division, under contract J0255026. The handbook was developed for use by individuals with knowledge and experience in both mineral engineering and cost estimation. The handbook was designed to produce a reliable prefeasibility type estimate, acurate to within 25% of the expected actual cost.

The first edition was introduced in 1975 and, accordingly, the costs therein reflected 1975 technology. In the decade since the introduction of the handbook, considerable technological change has taken place and mining and mineral processing costs have been significantly affected. Further, other important developments such as decreasing metal prices, rising labor costs, and environmental restraints have resulted in a series of austerity measures effected by the management of many mineral operations. In view of these considerations, a complete revision of the handbook was warranted.

In order to ensure adequate coverage of the 34 strategic commodities by the CES, it was necessary to reevaluate each cost section from the 1975 version of CES and also to develop a considerable number of new unit processes sections. The task of updating and revising the manual was assigned primarily to three Bureau groups. The Intermountain Field Operations Center (Denver, CO) was assigned the responsibility of providing updated replacement sections for the majority of the surface mining and mineral processing unit operations contained in the original manual, while the Western Field Operations Center (Spokane, WA) held primary responsibility for updating and supplementing the sections for underground mining. Additionally, several new mineral processing unit operations were provided by both field centers. Finally, 29 completely new unit operations sections were prepared by Pincock, Allen and Holt, Inc. under contract J0245002. The entire update project was coordinated by the Minerals Availability Field Office (Denver, CO).

The CES handbook consists of a series of costing sections, each corresponding to a specific mining or mineral processing unit process. Contained within each section is the methodology to estimate either the capital or operating cost for that unit process. The unit process sections may be used to generate costs through the use of either costing curves or formulas, depending on the option of the estimator. The cost curves are typically presented on a logarithmic scale of cost versus capacity and the corresponding cost formulas are (usually) of the form $Y = A(X)^B$, where X and Y represent the independent and dependent variables of size or capacity and cost, respectively. For the operating cost formulas and graphs presented for the various unit process throughout this handbook, the Y subscripts L, S, and E indicate labor, supplies, and equipment operation, respectively. All cost estimation methodologies contained in this manual have been prepared in January 1984 dollars and represent the prevailing technology at that date. None of the curves or equations in this handbook contain allowances for property and/or inventory taxes, general insurance or depreciation.

The reader will notice that all cost equations and curves are linear, logarithmic, or exponential, and that associated with each cost section is a range of applicability. The data obtained within these stated limits are reliable, but the same cannot be said for costs obtained by extrapolation outside of these limits. In most cases, the upper and lower limits encompass production parameters for actual mining and mineral processing operations used in the preparation of the unit process sections with values beyond tending to fall outside the range of current technology.

The data used in the development of this handbook was derived from information gleaned from a number of sources including industry contacts, equipment suppliers and vendors, Bureau files, and Government contractors. The major steps involved in the development were essentially the same for all unit processes, and involved the following progression:

1. Accumulation of data relating to each unit process through literature review, industry contacts, equipment vendors, etc., to provide the data base for development of the capital and operating cost estimates.

2. Determination of the types of the equipment for the unit process used in industry as of January 1984, and the establishment of the range of capacities for which the unit process is employed.

3. Selection of a minimum of three capacity data points for detailed cost analysis and subsequent preparation of a bottom-up cost estimate for each data point.

The majority of the data points corresponded to a capacity of an existing operation. In isolated cases where an existing operation of appropriate capacity could not be located, or because of insufficient data, the costs for an operation were modeled from the other estimates. In all cases, the limits of applicability stated for each section are within 15% of the maximum and minimum data points, respectively.

4. Calculation of the costing formulas and drafting of the cost curves. Generally, the costing formulas were derived through geometric regression analysis of the cost estimates prepared for each capacity, although a few curves are linear or exponential.

5. Verification of the cost formula through comparison with actual data. The total facility costs projected by the handbook have been demonstrated to fall within the limits of a prefeasibility estimate (i.e., within plus or minus 25% of actual costs).

METHODOLOGY

The CES handbooks for surface and underground mining and mineral processing are each divided into three major sections. The first of these sections, capital costs, involves the construction of the mine or mineral processing facility. The second section, operating costs, allows for the computation of the operating labor, supplies, and equipment operation of an existing or hypothetical operation. The last section, infrastructure, contains cost equations and curves for an assortment of infrastructure items.

Each cost generated by use of the costing handbook may be broken down into its respective subcomponents. A brief discussion on this aspect of the costing system, as applied to capital and operating costs, follows.

Capital Cost

The capital cost estimates were prepared to correspond to the actual range of capacities for which the unit processes are employed in industry. Detailed cost estimates were prepared for a minimum of three separate capacities covering this range. For the capital cost estimates, each unit process estimate was composed of the construction labor cost, the construction materials cost, a purchased equipment cost, and the cost of transportation. Each capital cost section gives a breakdown of these four components as a percentage of the total fixed capital cost for the unit process.

Modest contingencies, generally ranging from 5% to 10%, were applied to cover incidental items not specifically addressed in the estimates for some of the capital cost sections. However, it must be stressed that this contingency was applied only in areas where there was a degree of uncertainty on the part of the evaluator preparing the cost section and it must not be inferred that an overall blanket contingency has been applied.

Construction Labor

Construction labor costs were estimated from worker-hour requirements for each unit operation for each capacity studied. Average labor costs were determined from local union wage rates for a variety of job classifications common to mineral industry construction. The average labor wage rates applied to the worker-hour estimates

include labor burden and fringe benefits of 21% of the base wage rate. For this analysis, the construction labor burden and fringe benefits have been assumed to include the employer's contribution to union funds for health and welfare, vacations, holidays, sick leave, retirement, Social Security (FICA), Federal Unemployment Insurance, (FUI), State Unemployment Insurance (SUI), and Workmen's Compensation.

A shift adjustment factor has been included in some of the capital cost estimation sections for mining, since it is conceivable that certain operations may operate either one or three shifts per day. Since the base case sections were designed for two-shift-per-day operation, it was necessary to include a mechanism for adjusting the cost per day total for an alternative operating schedule. The job classifications and associated base wage rates used in the computation of the construction labor component of the capital costs are presented in Table 1.

Table 1.--Construction labor job classifications and hourly wage rates

Job	Wage[1]
Boilermaker, journeyman	$21.00
Boilermaker, apprentice	17.32
Carpenter, journeyman	20.50
Carpenter, apprentice	15.89
Concrete finisher, journeyman	21.40
Concrete finisher, apprentice	15.88
Electrician, journeyman	23.11
Electrician, apprentice	12.71
Equipment operator	19.15
Equipment operator, apprentice	15.80
Ironworker, journeyman	22.08
Ironworker, apprentice	16.01
Laborer	12.71
Millwright, journeyman	22.52
Millwright, apprentice	17.27
Painter, journeyman	19.23
Painter, apprentice	14.34
Pipefitter, journeyman	20.90
Pipefitter, apprentice	13.71

[1] Includes 21% burden and fringe benefits.

Construction Materials

The estimates for construction materials include support steel, steel reinforcing bars, concrete, sand and gravel, timber, etc. Also included are small handtools, welding rods, and other miscellaneous equipment. It was generally assumed that construction materials are readily available at the mine or construction site and that the freight cost associated with these materials is negligible.

Purchased Equipment

In the capital cost sections for both mining and mineral processing unit operations, purchased equipment refers to the major mining or process equipment directly associated with the operation. The development of the capital cost estimates for each unit process included the construction of a major equipment lists with the equipment sized according to the capacities analyzed.

Transportation

Transportation, or freight, costs have been estimated using the basis of a midwestern (Denver, CO) mine or construction site. In most cases, freight costs were estimated using the nearest supplier-vendor for each piece of equipment to calculate the total distance for the shipment. Average transportation rates were then applied to the distance to calculate the cost of transporting the major equipment items from the manufacturer to the construction site. In each capital cost section, the percentage of the fixed capital cost for the particular unit operation is given and can be applied to the cost generated by the costing formulas (or curve) to derive the transportation cost.

Adjustment Factors

Many unit process sections contain one or more adjustment factors that may be used to address circumstances other than those assumed for the development of the cost section. These factors are generally multiplied by the product of the cost formula (or the cost taken directly from the curve) to obtain a cost representative of these special circumstances.

All curves in this handbook have been adjusted to a common base with every effort having been made to present data representative of a typical application of the particular mining method or beneficiation process under consideration. Often, however, the estimator will be privy to information that can substantially upgrade the quality of the estimate through the judicious application of adjustment factors. In order to properly apply the adjustment factors, the estimator must be capable of discerning any differences between the method or process under consideration and that presented in this handbook. When the estimator encounters an abnormal situation, proper adjustment of curve data, either upward or downward, must be made. For that reason, whenever certain adjustment factors may apply they have been explained and referenced. Mention of some of the common adjustment factors has been omitted from the narratives in order to avoid repetition. These factors include the various cost indexes and the labor rate and power cost conversion methods, as well as more subtle variables such as rock hardness. Even though many variables have been considered in the preparation of the handbook, every mineral deposit has its own unique differences that the individual estimator must be able to recognize and include in the cost estimation.

Four general adjustment factors are common to almost every section within the cost estimation system handbook.

Shift factor: Consistent with industrial practice, most mine capital and operating cost sections were developed on the basis of a two-shift-per-day operation and mineral processing plant sections were developed using a three-shift-per-day operation. Departures from this basis are noted within each individual cost estimation section. To adjust for alternative operating schedules, the estimator should determine the quotient of the design basis number of shifts (n_1) divided by the actual number of shifts for the operation under consideration (n_2). The quotient can then be multiplied by the daily feed rate to obtain an adjusted daily feed rate. The adjusted daily feed rate is then substituted for the independent variable, X, in the cost equations.

Power factor: In all of the cost estimation sections, the cost of electrical power was assumed to be $0.05.kWh. To adjust the costs for a different power

rate, the estimator should multiply the power cost obtained from the cost equation (a percentage of the operating supplies curve) by the quotient of the actual power cost divided by the assumed power cost of \$0.05/kW·h.

Water factor: The cost of purchased water was taken to be \$0.10/m^3. To adjust the costs for a different water rate, the estimator should multiply the water cost obtained from the cost equation by the quotient of the actual water cost divided by the assumed water cost of \$0.10/m^3.

Sales tax: A uniform 4% sales tax was applied to the total fixed capital cost for each unit operation. This approach reflects the construction of a greenfield mine or mineral processing facility by an independent contractor. If the sales tax for the area being estimated differs from the standard 4%, then the appropriate adjustment to the total capital cost should be made.

Operating Cost

The operating costs presented in these sections include the mining and mineral processing costs and mine or plant overheads. The operating cost section for each unit process includes distinct formulas and curves allowing for the independent calculation of the operating labor cost, the operating supplies cost, and the equipment operation cost. Fixed charges of insurance, taxes, royalties, depreciation, packaging, product freight, selling expense, or general and research expense are not included. The costs associated with supervision are not included with the individual unit processes, but are included in aggregate form with the general and administrative expense curves.

Labor

The labor costs generated through the use of this handbook include both direct operating labor and maintenance labor. Each operating cost section of the handbook provides the relative percentages of direct and maintenance labor that may be applied to the aggregate operating labor cost generated by the costing formula. The text also presents a tabulated summary of the direct labor component of the operating labor cost, providing a breakdown of job classification and the average wage rates for the direct labor involved in the operation. An example listing of job classifications and wage rates used in the estimation of the operating labor costs is presented in Table 2.

Table 2.--Operating labor job classifications and hourly wage rates

Job	Wage[1]
Operations:	
Rotary drill operator	$16.78
Shovel operator	18.11
Truck driver	15.89
Cave miner	18.11
Production loader	16.33
Control room operator	17.23
Mill operator	16.78
Mill helper	13.66
Sampler	15.44
Mill laborer	11.68
Maintenance:	
Mechanic/welder "A"	16.78
Mechanic/welder "B"	16.33
Electrician	18.11
Instrumentation	18.11
Oiler	14.56
Machinist	17.32

[1] Includes 32% burden and fringe benefits.

All labor rates (costs) used in the preparation of curves are based on the Denver, CO area as of January 1984, and include an allowance of 32% to cover all applicable payroll burdens and fringe benefits. Shift differentials of $0.30 per hour for the second shift and $0.45 per hour for the third shift have been included in the labor estimates. Area and/or incentive bonus premiums are not included and the estimator's judgment must determine the application of adjustment factors for these items.

Supplies

The supplies portion of the operating cost sections is comprised of electrical power, natural gas, reagents and industrial chemicals and other consumables. A standard sales tax of four percent was added to all nonfuel items. The costs in table 3, reflective of January 1984, were used in preparing the estimates of supply operating costs:

Table 3.--Base case supply costs

Commodity	Unit	Cost
Fuel Oil	gal	$ 1.00
Natural Gas	1,000 ft^3	3.20
Coal, 84%-subbituminous	st	25.00
Electricity	kW•h	0.05

Equipment Operation

Equipment operation costs are considered to include fuel, lubrication, repair parts and tires for all process equipment related to the unit processes. The fuel costs used in the preparation of the cost estimates on which the equipment operation curves are based were those in effect in the Denver, CO, area in January 1984. The gasoline and diesel fuel costs were both $1.00/gal. A standard sales tax of 4% was added to all nonfuel items.

To adjust fuel costs to more recent, local rates, the user should first obtain the percentage of the total equipment operation cost due to fuel, and then multiply that percentage, in decimal form, by the current cost per gallon of gasoline or diesel fuel.

Adjustment Factors

Similar to the capital cost sections, many operating cost sections contain adjustment factors to address operating circumstances other than those that were assumed for the development of the costing section. Again, these factors are generally multiplied by the product of the costing formula (or the cost taken directly from the curve) to obtain a cost representative of these special circumstances. A more detailed explanation of the development and use of adjustment factors has been included in the previous discussion of capital costs.

Infrastructure

In addition to the unit process modules, a number of auxiliary sections representing the various infrastructure elements associated with mining and mineral processing operations have also been provided. These sections include long-distance transportation, loading facilities, storage, waste water treatment, access roads, townsite and camp operation, among others. The application of these sections is virtually the same as for the unit process sections.

COST UPDATING

The mining and mineral processing estimating procedures presented in the handbook, using individual cost component breakdowns, provide a methodology by which the base costs derived from the system can be adjusted to be applicable in different locations and/or be updated through time. Labor productivities can also be adjusted to reflect cost differences due to differences in manpower requirements.

Two methods may be used to adjust the labor cost curves. Method one, the more accurate of the two, is to use the prevailing labor rates for the area under consideration, in the year of desired escalation, and apply the appropriate payroll burdens and premiums. By dividing the new rate by the one given in the narratives, a labor adjustment multiplier is obtained, which is applied to the labor cost calculated from the formulas or from the curves. The second method is to use a labor rate for the area under consideration, in the base year. By dividing the new rate by the one given in the narrative, a labor adjustment multiplier is obtained, which is updated from either labor index number 1 or 2 (table 4). By dividing the index corresponding to the year of desired escalation by the one in January, 1984, a ratio is derived, which when combined with the labor adjustment multiplier is applied to the calculated labor cost. This factor can be used for all classes of labor throughout the estimate.

Table 4.--U.S. Cost indexes, 1980-85

	1980	1981	1982	1983	1984[1]	1985
Mining Wage............	9.19	10.06	10.82	11.27	11.56	11.90
Construction Wage......	2,767.0	3,025.0	3,345.0	3,587.0	3,679.0	3,747.0
Equipment/Repair Parts.	288.9	320.8	343.9	351.9	354.3	362.3
Bits and Related Steel.	305.0	333.8	339.0	343.4	354.1	355.6
Timber and Lumber......	325.6	325.1	310.8	352.6	353.2	340.0
Fuel...................	674.3	805.9	761.2	684.3	669.7	633.8
Explosives.............	251.1	288.9	298.9	302.1	301.3	312.8
Tires and Rubber.......	249.7	270.2	271.6	260.0	258.0	247.0
Construction Materials.	287.7	310.3	330.1	352.9	355.5	358.2
Industrial Materials...	274.2	304.1	312.3	315.7	319.2	323.9
Transportation.........	311.3	355.3	387.3	395.4	409.7	414.4

[1]January, base.

Operating cost differences due to varying productivities can be adjusted through the individual unit process labor costs or through the combination of the components of underground mining, surface mining, or mineral processing. Contained in the labor portion of the narrative of each unit operation is a weighted average labor rate of all laborers necessary for that particular unit operation. The number of workers per day for each unit operation can be calculated by dividing the daily adjusted base year labor cost by the product of the average labor rate and 8 h per shift. An adjustment can be made on each unit operation if the estimator replaces the number of workers per day calculated above with a new estimate and multiplies by the average labor rate times 8 to derive the new adjusted labor cost based on a new productivity. If specific information is not available on each unit operation, the user can compute the number of workers per day for each unit operation and add them to get the total workers for the mine or mineral processing plant being evaluated. A productivity ratio is determined by dividing the known number of workers per day by the computed value, which when multiplied by the total adjusted labor cost gives the new labor cost.

Often, productivities are expressed as metric tons per worker-shift or metric tons per worker-hour. If the previous calculation is carried further by introducing the capacities of the mines or processing plants, productivity ratios can be derived to adjust the labor costs.

Most of the supplies and equipment operation costs are composed of more than one component. In these cases, it is necessary to calculate the component cost for each index classification. By dividing the index corresponding to the year of desired escalation by the one for January 1984, for each component, a ratio is obtained that is multiplied by the calculated cost component. Combining these escalated components produces a final updated cost.

Electricity, natural gas, propane, and water costs do not have corresponding index classifications for updating. The method used to update these categories by location is to use the prevailing rates for the area under consideration, either in the base year or the year of desired escalation, and to divide the new rate by the one given in the narratives resulting in the adjustment factor. This factor is next multiplied by the corresponding cost from the curve to obtain the site-specific cost.

Cost Indexes

The mining wage rates index includes both mine and plant labor. This index includes skilled, unskilled, local, and expatriate labor along with burden and fringe benefits (employer's contribution to union funds for health and welfare, vacations, holidays, sick leave and retirement, Social Security, Federal and State Unemployment Insurance, and Workmen's Compensation).

The construction wage rate index includes all labor (see mining wage index for inclusions) employed in the construction of mines and mineral processing facilities.

The equipment and repair parts index relates to equipment and repair parts relevant to mining and mineral processing operations and related infrastructure, e.g., front-end loaders, shovels, load-haul-dumps (LHD's), trucks, jumbo drills, as well as crushers, grinding mills, flotation cells, thickeners, filters, etc.

The drill bits and related steel index includes steel for mining and mineral processing such as drill bits, pipe, fan liners, track, shovel and loader teeth and liners, etc., as well as replacement parts such as steel balls, rods, shell and head liners, scoop lips, etc.

The timber and lumber index covers the timber and lumber that is most readily available for applications such as cribbing, lagging, and supports in underground mining.

The fuel index covers refined fuel products weighted toward diesel. However, the fuel index is also considered applicable to other petroleum products.

The explosives index includes all types of blasting supplies, e.g., propellent powders, blasting caps, etc.

The tires and rubber index includes all types of tires applicable to mining operations, e.g., for LHD's, trucks, as well as other parts made of rubber such as conveyor or other belts for machinery.

The construction materials index is applicable to materials such as sand, gravel, cement, limestone, reinforcing rods, steel fasteners, etc., for use in construction of mine and mineral processing plants and related infrastructure.

The industrial materials index includes mining and mineral processing chemicals used in daily operations, e.g., wetting agents, mining reagents, dust depressants, flocculants, flotation reagents, etc.

The transportation index measures transport cost based upon an assessment of the country's normal freight transport network relevant to the mineral industry and could include, in addition to rail and truck, means such as barge and pipeline.

GUIDELINES FOR MINERAL PROCESSING COST ESTIMATION

The CES handbook is a tool to be used for capital and operating cost estimation and comparison. As with any tool, the skill of the user will ultimately determine the quality of the product. The evaluator must realize that the extent of thought and understanding in the input will directly affect the accuracy of the final result. When estimating the cost of an operating plant, as much information as pos-

sible should be compiled prior to cost estimation. When costing a proposed operation, it is imperative to develop a detailed flowsheet before using this handbook. The method providing the maximum economic benefit given the restrictions of mineralization, ore grade, ore throughput, geographic location, and availability of labor, supplies, and energy must be selected.

The mineral processing handbook includes individual cost estimation sections for unit operations associated with comminution, beneficiation, solid-liquid separation, hydrometallurgy, and special applications, as well as infrastructure and plant general and administrative costs. When using this system for estimating cost data for a mineral processing facility or for checking or verifying processing costs from an existing facility, a minimum amount of background information must be obtained. This will include geology, mining, economics, environmental, infrastructure, and any extreme circumstances that would have an impact on the costs.

An explanation is included with each cost section. Each explanation lists the cost items used to develop the cost section, and specifies what is covered. Since the content of many of the mineral processing sections is so variable, each explanation must be read carefully and fully understood. Only by understanding the scope of each section can the estimator be assured that every required item will be accounted for once, and only once, in the final cost estimate.

The successful utilization of this mineral processing cost estimation handbook is dependent on the completion of the following procedure:

1. Preparatory study of the particular process under consideration.
2. Establishment of a materials balance and process flowsheet.
3. Selection of the appropriate cost sections.
4. Calculation of capital and operating costs for each section.
5. Summation of costs.

The following pages present some guidelines for the application of the mineral processing cost estimation system. As with any guidelines, numerous exceptions exist, and many situations are not considered. In the final account, the individual evaluator's knowledge of the basic principles of engineering and of the particular processing system under study will determine the accuracy of the estimate.

Preparation

Geology

Geologic information such as the available ore reserves and grade is a necessary component of the cost estimation method. The major type and character of the mineralization is critical to the design of the extraction system. Ore types can be classified as massive, intergrown, or disseminated. The ore type will directly affect the choice of the mineral processing method to be employed in the extraction of the minerals. For example, the comminution circuits must be designed to ensure that the desired minerals are adequately unlocked to achieve sufficient grade and recovery.

Mining

The mineral processing facility must be designed to operate in harmony with the mine plan. Therefore, for costing of a new facility, it is necessary to know the

proposed capacity and operating schedule of the mine prior to beginning the development of the metallurgical flowsheet. If multiple ore sources are a possibility, then each of the feed sources must be carefully analyzed.

Economics

The economics of the various processing methods available must of course be considered. Once the characteristics of the mineralization have been delineated, the choices of a general extraction method are narrowed significantly. In general, the flowsheet considered initially for any ore must be based on the type of separation that appears to be most effective, considering the relative value of the recoverable minerals, the types of recoverable minerals, and market and location considerations. Occasionally, more than one beneficiation method may appear to be applicable to a given ore. At this point, if no other factors prohibit the choice, the least expensive remaining alternative is selected.

The process selected will ultimately rest on those factors (location, capacity, etc.) that will strongly influence the overall project economics. The best overall metallurgical plan may not produce the most favorable economics, therefore, optimum recovery is not necessarily maximum recovery.

Environmental

Although the benefits are often economically intangible, a prudent engineer must certainly study the advantages of reducing the environmental impact. Serious environmental problems associated with mineral processing operations include aesthetics, noise, dust, and solid and liquid waste treatment and disposal.

Other Parameters

Before deciding on a processing technique, all remaining available information should be examined. Environmental, geographical, personnel, and financial restrictions may each influence design. Since many sections have factors for unusual situations, this information will also increase the exactness of the cost estimation process.

Geographical characteristics and plant site location also affect the selection of the method of extraction. In rugged or remote areas, it may prove difficult and expensive to bring in large equipment and operating supplies. In such a case, the most economically effective alternatives may include labor-intensive methods or the selection of a less effective extraction scheme. Mineral processing plant design in extremely remote areas may be governed by the availability of power.

The labor force deserves careful attention during the design process. If skilled labor is unavailable locally, a highly mechanized facility may prove more economically attractive than importing personnel. Unskilled local labor, if plentiful, indicates the necessity of a labor-intensive method using simpler equipment. Some labor skills are easily transferable, and should be used to advantage.

Flowsheet and Material Balance

In order to effectively apply the costing system, the estimator should develop a reasonably detailed flowsheet and material balance incorporating all operations to be costed. A comprehensive process flow diagram and material balance will enable

the estimator to apply the system rapidly, as most of the formulas or cost curves generate costs directly as a function of capacity (usually metric tons per day). This preparatory work should be sufficiently detailed to establish the grades and recoveries for all major product streams as well as to delineate the mass flow rates (both solid and liquid) for all major product streams. Finally, any special information (required for adjustment factors) should be noted as it will enhance the accuracy of the final estimate.

The estimator must first obtain the following minimum information to generate the costs for a desired actual or proposed operation:

The processing method employed and any peculiarities associated with the deposit.

The input and output streams for all unit operations.

The applicable labor rates, number of shifts operated per day, and water and electrical rates.

Once the general process flowsheet has been established, it is combined with the proper auxiliary systems to complete the plant design. This entails the inclusion of buildings, vehicles, administration, communication, electrical, and water systems, along with any other items required for operation. All sections required for the cost estimate should be studied to determine other information required for adjustment factors. In order to obtain the best results, the estimator should proceed through the sections in the sequence they are presented in the handbook.

Because the handbook was developed expressly for the purpose of calculating total plant costs, the user is cautioned against using costs developed in any single section or, especially, in combination with costs derived through other methods. For maximum accuracy, the costs should be developed for a complete facility.

Selection of Processing Sections

The initial step in using this handbook is the selection of sections and individual formulae and curves within the sections to be used in the evaluation. It is presumed the estimator will have adequate knowledge of mineral processing engineering and cost estimation procedures before attempting to prepare an estimate using the methods presented herein. After the data requirements have been prepared, the sections that apply should be studied until their contents are fully understood.

Mineral processing can be broadly defined as the treatment of raw materials (minerals) from the earth's surface to yield marketable products by methods that in general do not destroy the physical or chemical identity of the minerals. Separation is accomplished primarily by exploiting the physical differences between gangue and valuable minerals.

The general processes covered by this handbook include the following:

1.) Comminution
2.) Beneficiation
3.) Solid-liquid separation
4.) Hydrometallurgy
5.) Special applications

Although hydrometallurgy and some of the special applications fall outside the definition of mineral processing, they have been included within the handbook because of their close relationship with mining and mineral processing operations.

The following narrative reviews the major unit operations encompassed by mineral processing with emphasis on the contents of this handbook.

Comminution

Crushing: Crushing reduces run-of-mine ore to fragments with the coarsest (final) product being 1/4 to 3/8 in. Crushing generally takes place in two or three stages: Primary or coarse crushing reduces run-of-mine ore (maximum 60 diameter rock) down to a 6-to 8-in product through the use of either jaw or gyratory crushers. Secondary crushing takes the primary crushing product and reduces it in turn to a 3- to 2-in product. Gyratory or cone crushers are the usual choices for secondary crushing applications. Finally, a tertiary stage may be included to reduce the ore to a 1/4- to 1/2-in size. Cone crushers are almost exclusively used for tertiary crushing.

Grinding: Grinding composes the final stage of size reduction or particle liberation of ores. Generally the grinding circuit is designed to reduce a maximum upper feed range of approximately 10,000 mi (3/8/in) to some upper limiting product size between 35 and 200 mesh (420 to 74 mi). The optimum product size is dictated by combination of technical and economic considerations. Grinding can be accomplished in a variety of mills, typically rod mills and ball mills get the bulk of the applications, although autogenous and semiautogenous mills area becoming increasingly important.

Beneficiation

Flotation: Flotation is a physiochemical process for the separation of finely divided solids from one another. Separation of these dissimilar, discrete solids from each other is effected by the selective attachment of the particle to either a gas or a liquid phase. This mechanism is, in most cases, greatly assisted by modification of the particle surface by surfactants.

Gravity separation: If liberation of the desired mineral particles occurs at a relatively coarse size and there is a marked specific gravity difference between the value mineral(s) and the gangue, then gravity concentration methods such as the following may be employed.

1. Methods that depend on differing buoyancy between two particles of different densities when placed in a liquid of intermediate density.
2. Methods that depend on particle inertia resulting from both density and size difference. Important properties include particle size, density, fluid resistance, particle shape, and interparticle interference.

A brief discussion of some of the important gravity separation methods included in this handbook follows.

Heavy media: Heavy media process consists of continuously feeding a stream of crushed and washed (deslimed) ore into a fluid within a vessel so arranged that the float (light) and sink (heavy) products are continuously discharged along with the medium. The process is applicable to both metallic and nonmetallic minerals of size ranging from 8 in down to 65 mesh.

Jigs: Jigging is a form of gravity concentration carried out by pulsation of water through a screen that lies on a bed of crushed and sized ore. A mixture of sized particles of varying density is continuously fed into a box closed by screen on the underside through which water pulsates, a bed of heavier particles forms in the box above the screen. Concentrate is drawn off the top of the screen at intervals by means of a dam--the hutch product is removed through a valve.

Spirals: Spirals make use of a combination of centrifugal action, film flow, and heavy media separation forces. A spiral consists of descending spiral launder with modified semicircular cross section. Pulp is fed to the top of the spiral and as it flows downward, heavy particles concentrate in a band along the inner side of the pulp stream.

Tables: Shaking tables can be used for gravity separation when the materials are too fine for effective separation by jigging (approximately minus 20 mesh).

Other beneficiation processes included in the handbook are photometric separation and magnetic separation. These sections are applicable only to certain mineral commodities and should be applied with caution.

Solid-liquid separation

The solid-liquid separation sections have been designed to complement the beneficiation sections, however they may also be applied to the hydro- metallurgy sections. Capital and operating cost sections are provided for thickening, filtration (disk, drum, pressure, centrifugal), and countercurrent decantation. The importance of utilizing the adjustment factors provided in each section cannot be overemphasized for solid-liquid separation.

Hydrometallurgy

The field of hydrometallurgy involves the recovery of valuable components from ores or concentrates by relatively low temperature reactions accomplished in an aqueous phase. The three distinct operations can be identified in any hydrometallurgical flowsheet:

1. Leaching.
2. Solution concentration and/or purification.
3. Product recovery.

Leaching: The various leaching processes that are encountered can be classified with respect to reaction chemistry. Generally, the particular lixiviant selected for a given raw material is one that results in good selectivity for the valuable components to be recovered. If many components of the raw material are dissolved, then the subsequent leach liquor concentration and purification step will be more difficult. Leaching systems extend from the leaching of marginal low-grade ore in which there is no materials handling to the leaching of high-grade concentrates produced from physical and physiochemical separations by mineral processing technology.

Solution concentration and purification: Impurity removal is accomplished by a number of techniques in order to prepare the leach solution for product recovery. These techniques can be conveniently classified according to the following categories:

1. Solvent extraction.
2. Precipitation.
3. Cementation.
4. Ion exchange.

The application of any one of these processes depends mainly on the impurities to be removed and the component to be recovered. In some instances this intermediate stage of processing will involve the selective recovery of a solid phase containing the valuable component, e.g., copper cementation from dump leach liquors. In other instances, impurities may be removed (either in the solid state or in aqueous stream) with the valuable component to be recovered from a concentrated, purified solution, e.g., rejection of impurity components in raffinite during solvent extraction of uranium, copper, or other metals.

Product Recovery

The valuable component is finally converted into a marketable product with associated quality specifications. The product recovery phase of hydrometallurgy may involve purification of a solid phase or recovery from a concentrated purified aqueous solution. Common techniques employed for product recovery include

1. Gaseous reduction
2. Electrolysis
3. Precipitation

The hydrometallurgical sections included within this handbook are highly commodity specific. Most of the sections tend to cover a complete process rather than discrete unit operations. The estimator is advised to carefully read the text of each section to determine exactly what is included to avoid double counting.

Special Applications

This category encompasses a number of unit operations that do not readily fit the other descriptors. Included are unusual mineral processing techniques, chemical engineering processes, and thermal processes.

EXAMPLE APPLICATION OF CES: SEMIAUTOGENOUS GRINDING

For purposes of illustration, the following example briefly outlines the procedure for calculating capital and operating costs for a single unit process for mineral processing. A similar sequence of calculations is required for any of the unit process sections contained in this handbook. The unit process sections for calculation of the capital and operating costs for semiautogenous grinding are the subject of this example. A hypothetical capacity of 20,000 mtpd of ore has been assumed.

Capital Cost

Two curves are presented in the handbook for costing semiautogenous grinding (SAG) circuits. The proper formula for the calculation of the capital cost of the 20,000 mtpd circuit considered in this example is:

$$Y = 563.836(X)^{0.972}$$

By substitution:

$$Y = (563.836)(20,000)^{0.972}$$

$$Y = \$8,546,000$$

The capital cost breakdown indicates that 77% of the cost is purchased equipment, 16% is construction labor, 4% is construction materials, and 3% is transportation (freight). Therefore, the capital cost breakdown may be calculated as follows:

Purchased equipment......	(0.77)(8,546,000)=	\$6,615,000
Construction Labor.......	(0.16)(8,546,000)=	1,401,000
Construction Materials...	(0.04)(8,546,000)=	308,000
Transportation...........	(0.03)(8,546,000)=	222,000
Total..................		8,546,000

Operating Labor

The first objective of CES involves the calculation of the total labor (direct operating labor plus maintenance, including fringes and burden) for the unit process under consideration. In the case of SAG, the formula for calculating the operating labor cost (per day) is

$$Y_L = 116.035(X)^{0.304}$$

By substitution: $Y_L = 116.035(20{,}000)^{0.304}$

$$Y_L = \$2{,}356/\text{day}$$

Subsequently, the relative amounts for direct operating labor and maintenance labor can be calculated using the percentages given in the text of 45% mine labor and 55% maintenance labor.

Operating labor..........	(0.45)(2356) = \$1,060/day
Maintenance labor........	(0.55)(2356) = 1,296/day
Total labor............	2,356/day

Operating Supplies

The cost per day of operating supplies for SAG grinding is calculated by substituting the capacity, 20,000 mtpd, into the equation:

$$Y_S = 0.614(X)^{0.986}$$

By substitution: $Y_S = 0.614(20{,}000)^{0.986}$

$$Y_S = \$10{,}690/\text{day}$$

The costs of the components of the operating supplies cost in this case consists 100% of electrical power.

Equipment Operation

The cost per day of equipment operation for SAG grinding is calculated by substituting the capacity, 20,000 mtpd, into the equation:

$$Y_E = 0.312(X)^{0.998}$$

By substitution: $Y_S = 0.312(20{,}000)^{0.998}$

$$Y_S = \$6{,}118/\text{day}$$

The costs of the components of the equipment operation cost can then be calculated using the percentages given in the text:

Wear materials (liners, balls).......	(0.94)(6118) =	$5,751/day
Replacement parts....................	(0.06)(6118) =	367/day
Total equipment operation cost.....		6,118/day

Adjustment Factors

To illustrate the application of adjustment factors, assume that fully autogenous grinding of a sulfide ore (power requirement of 14.3 kW•h/mt) is desired. Since the base section was designed for semiautogenous grinding of an ore with a power requirement of 10.44 kW•h/mt, two adjustment factors will be required: Autogenous grinding and hardness.

Capital Cost

Autogenous grinding factor:
$(F_L) = 0.995$

Hardness factor:
$(F) = (10.44/N)^{-0.959}$
where N is the new power requirement, in kilowatt hours per metric ton.

$(F) = (10.44/14.3)^{-0.959} = 1.43$

Total Adjusted Costs

Total capital cost $8,546,000 X 0.995 X 1.43 = $12,160,000

Operating Cost

Autogenous grinding factor:
Labor factor $(F_L) = 0.911$

Supply factor $(F_S) = 1.000$

Equipment operation factor $(F_E) = 0.270$

Hardness factor:
$(F) = N/10.44$
where N is the new power requirement. in kilowatt hours per metric ton.
$(F) = 14.3/10.44 = 1.37$

Total Adjusted Costs

Total labor cost $2,356/day X 0.911 X 1.37 = $2,940/day

Total supplies cost $6,118/day X 1.000 X 1.37 = $8,382/day

Total equipment operation cost $10,690/day X 0.270 X 1.37 = $3,925/day

Summation of Costs

Finally, the estimator should sum the capital and operating costs. Significant figures should be taken into account at this time if the estimator has not already done so. The cost equations given in the text have not been reduced to significant figures, as they are the product of a statistical analysis. It is recommended that the estimator express no more than three significant figures (depending on the precision of the input data).

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Van Waters & Rogers
WEMCO Corp.
Westinghouse Electric Corp.
Worthington Pump Co.

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.1. COMMINUTION

6.1.1.1. CRUSHING

The capital cost for crushing includes the acquisition and installation of equipment to crush run-of-mine ore to a size suitable for grinding or other beneficiation operations. The crushing circuit includes primary, secondary, and, if necessary, tertiary crusher, screens, and the attendant materials handling equipment (feeders, belt conveyors, etc.). The curve is valid for secondary and tertiary crushing when the mobile crushing section (6.1.1.2.) is used. The total capital cost is based on a single cost curve having a feed rate (X), in metric tons of ore per day. The curve is valid for operations between 500 and 100,000 mtpd, operating three shifts per day.

BASE CURVE

The base curve was developed for the reduction of a medium hard ore (work index of 14.3 kW·h/mt) from run of mine size to 80% passing 1.27 cm (0.5 in.). The process commences with the introduction of the ore into the primary crusher and terminates with the final crusher discharge conveyor.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	14%
Construction supply cost.....	13%
Purchased equipment cost.....	71%
Transportation cost..........	2%

The total capital cost is $(Y_C) = 2{,}392.492(X)^{0.775}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 334.949(X)^{0.775}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 311.024(X)^{0.775}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 1{,}746.519(X)^{0.775}$

ADJUSTMENT FACTORS

<u>Ore Hardness Factor</u> The base curves are premised on an ore hardness (work index) of 14.3 kW·h/mt. To adjust for a different work index, multiply the cost obtained from the curve by the following factor:

Ore hardness factor $(F_H) = 0.995(14.3/I)^{-0.744}$
where I = new work index, in kilowatt hours per metric ton.

<u>Product Size Factor</u> The particle size of the crushed product is ultimately dependent on the discharge opening setting of the final crusher(s) in the series. To adjust for a crusher discharge setting other than 1.27 cm, multiply the cost obtained from the curve by the following factor:

Product size factor $(F_S) = 1.122(S)^{-0.714}$
where S = new crusher discharge setting, in centimeters.

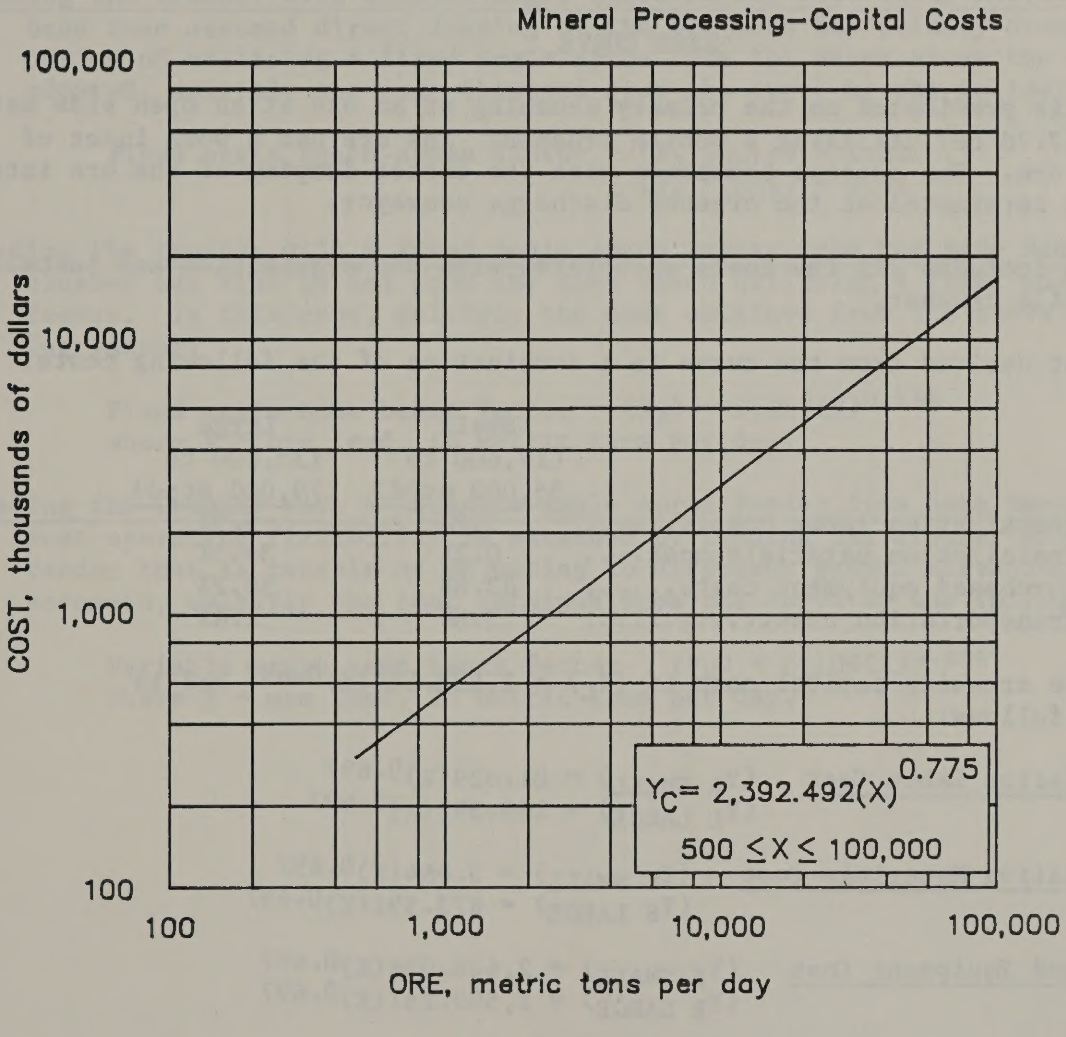
Mobile Crushing Factor In the event that mobile crushers are to be used as the primary crushers, multiply the costs obtained from the curves by the following factors to determine the costs of secondary and tertiary crushing:

Mobile crushing factor $(F_M) = 0.676$

Long Distance Conveyors The base curves are predicated on the assumption that the primary crusher(s) are reasonably proximate to the fine crushing facility. If the distance between primary and secondary crushing facilities exceeds 150 m, a long distance conveyor should be included in the cost estimate (see section 6.1.7.5.).

Coarse Ore Storage Factor The base curve contains no allowance for coarse ore storage. The capital cost for coarse ore storage facilities can be calculated from the following equation and added to the total cost:

Coarse ore storage factor $(F_C) = 224.000(C)^{0.957}$
where C = capacity of coarse ore storage, in metric tons.



6.1.1.1. Crushing

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.1. COMMINUTION

6.1.1.2. MOBILE CRUSHING

The capital cost for mobile crushing is the for acquisition and installation of equipment needed to perform primary crushing on an ore. The mobile crusher includes feed arrangement, crusher, rock breaker and discharge conveyor. The total capital cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of ore per day. The curve is valid for operations between 17,600 and 79,000 mtpd, operating three shifts per day.

BASE CURVE

The base curve is predicated on the primary crushing of an ore at an open side setting of 7 in (17.78 cm) utilizing a mobile crusher. The ore has a work index of 14.3 kW•/mt of ore. The process commences with the direct dumping of the ore into the crusher and terminates at the crusher discharge conveyor.

The cost curves includes all the costs associated with the acquisition and installation of the mobile crusher.

The capital cost derived from the curve is a combination of the following costs:

	Small (17,600 to 35,000 mtpd)	Large (35,000 to 79,000 mtpd)
Installation labor cost........	3.2%	5.9%
Installation materials cost....	0.2%	34.5%
Purchased equipment cost.......	83.8%	58.2%
Transportation cost............	12.8%	1.4%

The total mobile crushing capital cost is $(Y_C) = 2{,}532.149(X)^{0.697}$ and is distributed as follows:

(L) <u>Installation Labor Cost</u> $(Y_{L\ SMALL}) = 81.029(X)^{0.697}$
$(Y_{L\ LARGE}) = 149.397(X)^{0.697}$

(S) <u>Installation Materials Cost</u> $(Y_{S\ SMALL}) = 5.064(X)^{0.697}$
$(Y_{S\ LARGE}) = 873.591(X)^{0.697}$

(E) <u>Purchased Equipment Cost</u> $(Y_{E\ SMALL}) = 2{,}446.056(X)^{0.697}$
$(Y_{E\ LARGE}) = 1{,}509.161(X)^{0.697}$

At production rates less than 35,000 mtpd, the mobile crusher consists of preassembled units which are, for the most part, factory built and require only minimal on-site erection.

ADJUSTMENT FACTORS

<u>Ore Hardness Factor</u> The base curve is based on an ore hardness of 14.3 kW•h/mt. To adjust for a different work index, multiply the cost obtained from the curve by

the following factor:

Ore hardness factor $(F_H) = 0.1545/(I)^{-0.702}$
where I = new work index, in kilowatt hours per metric ton.

Crusher Setting Factor The base curve is premised on an open side crushing setting of 17.78 cm (7 in). To adjust for a new crusher setting, multiply the cost obtained from the curve by the following factor:

Crusher setting factor $(F_S) = 0.120(S)^{0.734}$
where S = new crusher setting, in centimeters.

Feeding the Crusher with a Fixed Angle Apron Feeder from Bench Above Factor The base case assumed direct dumping of the ore into the primary crusher. If the option of utilizing a fixed angle apron from the bench above the crusher is adopted, multiply the cost obtained from the curve by the following factor:

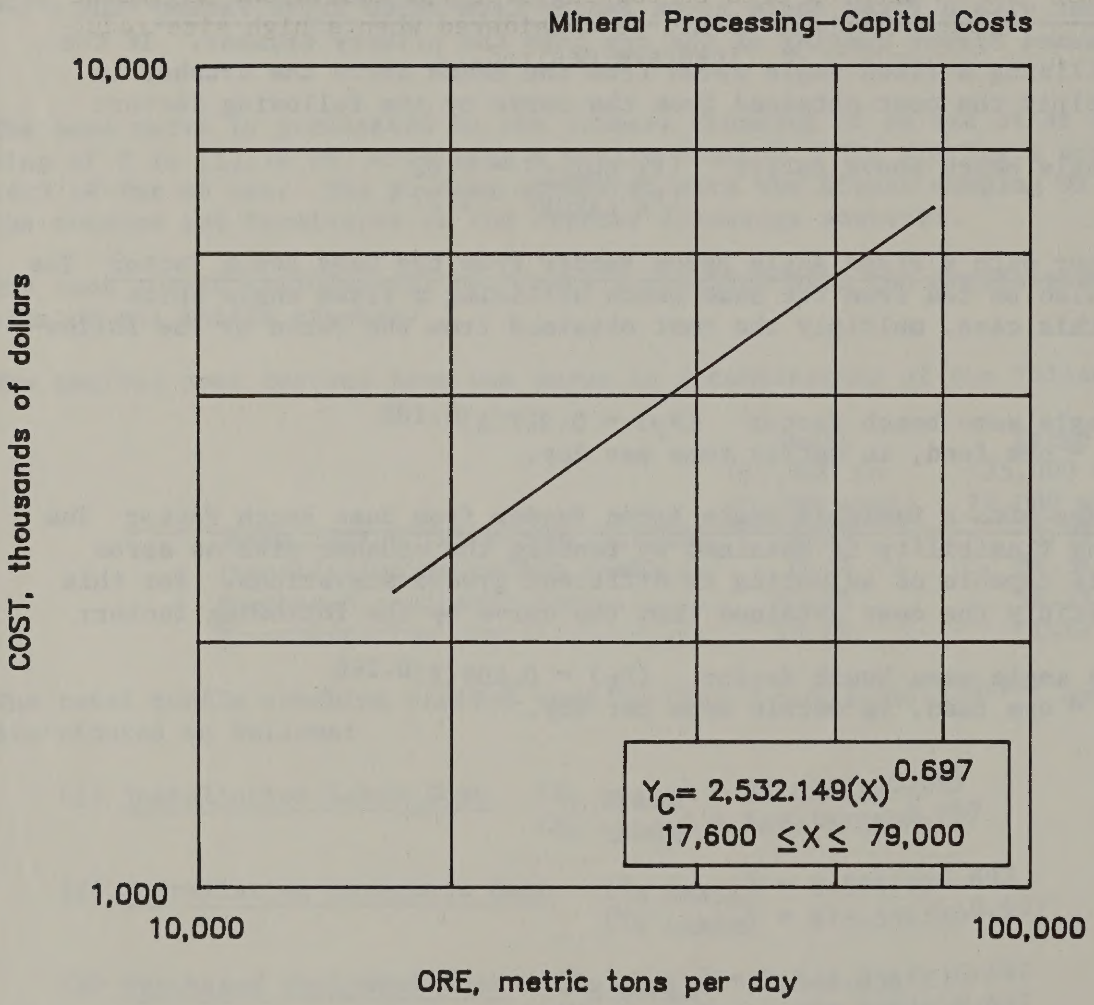
Fixed angle bench above factor $(F_{A\ SMALL}) = 1.22$
$(F_{A\ LARGE}) = 1.52$

Feeding the Crusher with a Fixed Angle Apron Feeder from the Same Bench Factor The crusher can also be fed from the same bench utilizing a fixed angle apron feeder. In this case, multiply the cost obtained from the curve by the following factor:

Fixed angle same bench factor $(F_F) = 0.217(X)^{0.188}$
where X = ore feed, in metric tons per day.

Feeding the Crusher with a Variable Angle Apron Feeder from Same Bench Factor The most operating flexibility is obtained by feeding the crusher with an apron feeder that is capable of adjusting to different ground elevations. For this scenario, multiply the cost obtained from the curve by the following factor:

Variable angle same bench factor $(F_V) = 0.109(X)^{0.266}$
where X = ore feed, in metric tons per day.



6.1.1.2. Mobile crushing

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.1. COMMINUTION

6.1.1.3. IMPACT CRUSHING

Impact crushers have a limited application in the mining industry but are effective on relatively nonabrasive ores such as soft iron ores, phosphate, trona, gypsum, and some limestones. This type of crusher is used to reduce ores that tend to be plastic and/or tend to pack when crushing forces are applied slowly, as in the case of jaw or gyratory crushers. Impact crushers depend on high hammer velocities for crushing and should not be used on ores containing over 15% equivalent silica because of high wear. Impact crushers should be considered when a high size reduction ratio and a large percentage of fines are desired.

BASE CURVE

Impact crushing capital cost includes all costs associated with acquisition and installation of primary and secondary impact crushers, surge bins, feeders, screens, conveyors, and foundations. Impact crushing facility capital cost is based on a single cost curve having a feed rate (X), in metric tons of mine run ore per day, that is reduced to minus 0.95 cm (3/8 in.). The curve is valid for operations between 1,200 and 20,000 mtpd, operating two shifts per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	10%
Construction supply cost.....	9%
Purchased equipment cost.....	79%
Transportation cost..........	2%

A typical breakdown of the major cost components is

Primary impact crushers......	20%
Secondary impact crushers....	30%
Screens......................	12%
Feeders......................	11%
Surge bins...................	20%
Conveyors....................	7%

The total capital cost is $(Y_C) = 6{,}743.170(X)^{0.609}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 674.317(X)^{0.609}$

(S) Construction Supply Cost $(Y_S) = 606.885(X)^{0.609}$

(E) Purchased Equipment Cost $(Y_E) = 5{,}461.968(X)^{0.609}$

ADJUSTMENT FACTORS

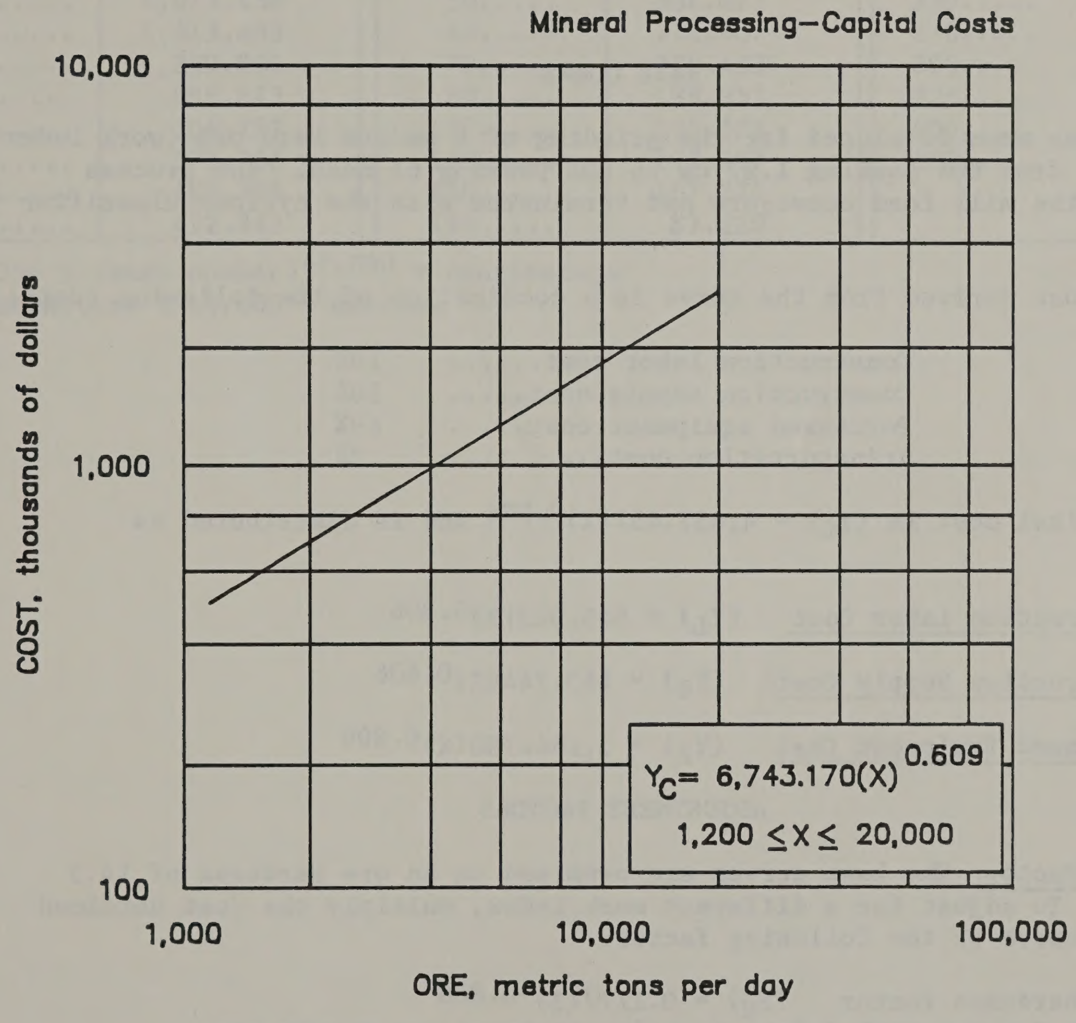
Alternative Application If mine run ore is minus 20 cm (8 in) because of mining technique (continuous miner, conveyor feeder breaker, etc.) then primary impact

crushers are not required. Use the following cost equation in place of $Y(_C)$, based on a daily feed rate (X) and a two-shift-per-day schedule, only if primary impact crushers are not required:

$$\text{Alternative application} \quad (Y_{C\ ALTERNATIVE}) = 729.000(X)^{0.782}$$

where X = ore feed, in metric tons per day.

Shift-Feed Rate Factor Due to high maintenance requirements, impact crushers are limited to not more than two shifts per day. If the crushing facility operates one shift per day, multiply the daily feed rate (metric tons per day) by two, then enter the adjusted daily feed rate into the cost equation.



6.1.1.3. Impact crushing

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.2. COMMINUTION

6.1.2.1. GRINDING

The capital cost for grinding includes the acquisition and installation of equipment to grind run-of-mine ore to a size suitable for further beneficiation operations. The major equipment associated with the grinding circuit includes rod mills, ball mills, feeders, conveyors, pumps, and classifiers. The total capital cost is based on a single cost curve having a feed rate (X), in metric tons of ore per day. The curve is valid for operations between 380 and 100,000 mtpd, operating three shifts per day.

BASE CURVE

The base curves were developed for the grinding of a medium hard ore (work index of 14.3 kW·h/mt) from 80% passing 1.27 cm to 80% passing 65 mesh. The process commences at the mill feed conveyors and terminates with the cyclone classifier overflow.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	19%
Construction supply cost.....	10%
Purchased equipment cost.....	69%
Transportation cost..........	2%

The total capital cost is $(Y_C) = 4{,}457.437(X)^{0.806}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 846.913(X)^{0.806}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 445.744(X)^{0.806}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 3{,}164.780(X)^{0.806}$

ADJUSTMENT FACTORS

<u>Ore Hardness Factor</u> The base curves are premised on an ore hardness of 14.3 kW·h/mt. To adjust for a different work index, multiply the cost obtained from the curve by the following factor:

Ore hardness factor $(F_H) = 0.117/(I)^{-0.806}$
where I = new work index, in kilowatt hours per metric ton.

<u>Size Factor</u> The base curve is predicated on grinding crushed ore of 80% passing 1.27 cm to a final particle size of 80% passing 65 mesh. To allow for variation in either the particle size of the feed to the grinding circuit or of the ground ore, multiply the cost obtained from the curve by the following factor:

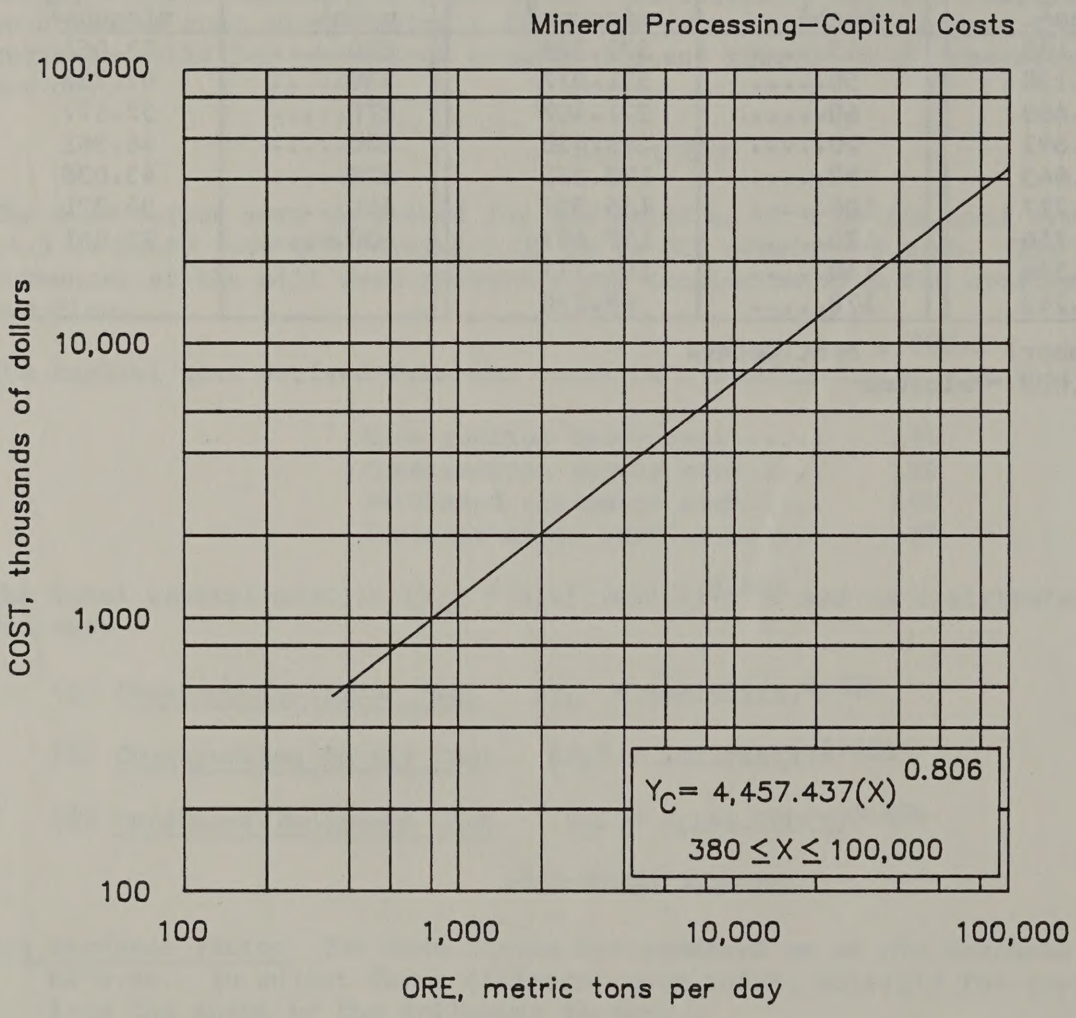
Product size factor $(F_S) = (S/0.055)^{0.806}$
where $S = [(1/(P)^{0.5})-(1/(F)^{0.5})]$,
F = particle size, in microns passing 80% of the feed to the grinding circuit,
and P = particle size, in microns passing 80% of the final product.

The following tabulation gives mesh sizes versus microns.

Mesh sizes versus microns

mesh[1]	microns[2]	mesh[1]	microns[2]	mesh[1]	microns[2]
2.....	11,058.183	45.....	371.368	200.....	73.061
5.....	4,073.138	50.....	331.077	230.....	62.737
10.....	1,913.403	60.....	271.407	270.....	52.677
15.....	1,229.892	70.....	229.430	300.....	46.961
20.....	898.843	80.....	198.353	325.....	43.038
25.....	704.777	100.....	155.527	400.....	34.321
30.....	577.756	120.....	127.497	600.....	22.061
35.....	488.396	140.....	107.777		
40.....	422.242	170.....	87.220		

[1] $2.354 \times (\text{mesh number})^{-1.090}$ = centimeters
[2] Centimeters X 10,000 = microns



6.1.2.1. Grinding

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.2. COMMINUTION

6.1.2.2. SEMIAUTOGENOUS GRINDING

The capital cost for semiautogenous grinding (SAG) is for the acquisition and installation of equipment needed to process an ore at a given particular size. The semiautogenous circuit includes feed conveyors, grinding mills, screens, sumps, and pumps (as needed).

BASE CURVE

The base curve is predicated on processing a sulfide ore from minus 6 to 9 in (15.2-22.9 cm) into a slurry for subsequent ball or pebble milling. The product of the primary SAG mill is a nominal minus 3/8 in (0.95 cm). The power required is 14 hp•h/mt based upon the installed mill horsepower being completely pulled.

The total capital cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of ore per day. The curves are valid for operations between 330 and 11,600 mt (a single mill of varying size) and between 11,600 and 111,800 mtpd, operating one shift per day.

The cost curves include all the costs associated with the acquisition and installation of the necessary conveyors, mills, screens and pumps.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	16.4%
Construction supply cost.....	3.6%
Purchased equipment cost.....	77.3%
Transportation cost..........	2.7%

The capital cost for a small semiautogenous mill (330 to 11,600 mtpd) is $(Y_{C\ SMALL}) = 47{,}897.164(X)^{0.467}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_{L\ SMALL}) = 8{,}142.518(X)^{0.467}$

(S) <u>Construction Supply Cost</u> $(Y_{S\ SMALL}) = 2{,}394.858(X)^{0.467}$

(E) <u>Purchased Equipment Cost</u> $(Y_{E\ SMALL}) = 37{,}359.788(X)^{0.467}$

The capital cost for a large semiautogenous mill (11,600 to 111,800 mtpd) is $(Y_{C\ LARGE}) = 563.836(X)^{0.972}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_{L\ LARGE}) = 95.852(X)^{0.972}$

(S) <u>Construction Supply Cost</u> $(Y_{S\ LARGE}) = 28.192(X)^{0.972}$

(E) <u>Purchased Equipment Cost</u> $(Y_{E\ LARGE}) = 439.792(X)^{0.972}$

ADJUSTMENT FACTORS

Single-Stage (SAG) Grinding Factor If the SAG mill is to be used for single stage grinding, i.e. the SAG mill operates in closed circuit with cyclones to produce the grinding circuit final product, multiply the cost obtained from the curve by the following factor:

Single stage grinding factor $(F_S) = 1.299(X)^{-0.014}$
where X = milling rate, in metric tons per day.

The above assumes a required power input of 14 hp•h/mt. It must be cautioned that the use of a SAG mill as the only stage of grinding must be predicated upon extensive testing.

Hardness Factor The required energy input for the base SAG mill cases is 14 hp•h/mt (assuming full power draw on the mill motors). The only means of determining the required power input is to perform large-scale batch tests or pilot testing. To adjust for different required power inputs, multiply the cost obtained from the curve by the following factor:

Hardness factor $(F_H) = 0.08373/(N)^{-0.959}$
where N = new power requirements, in horsepower hours per metric ton

Uranium Factor The processing of uranium ores represents a special case for SAG milling. SAG mills can operate as single stage grinding circuits processing uranium ores at relatively low power input (4 hp•h/mt). If uranium ores are being processed, multiply the cost obtained from the curve by the following factor:

Uranium factor $(F_U) = 0.306(X)^{0.063}$
where X = feed rate, in metric tons ore per day.

Autogenous Grinding (Sulfide) Factor The base curve for SAG mills in a two stage circuit can be adjusted to reflect autogenous grinding in a two stage circuit, assuming the same power requirements for grinding (14 hp•h/mt). Multiply the cost obtained from the curve by the following factor:

Autogenous grinding (sulfide) factor $(F_A) = 0.995$

The use of autogenous grinding normally require more power input per metric ton than SAG and the necessary power requirements must be determined by testing.

Iron Ore (SAG) Factor To adjust for the grinding of taconite in a two-stage circuit with the primary mill being a SAG mill, multiply the cost obtained from the curve by the following factor:

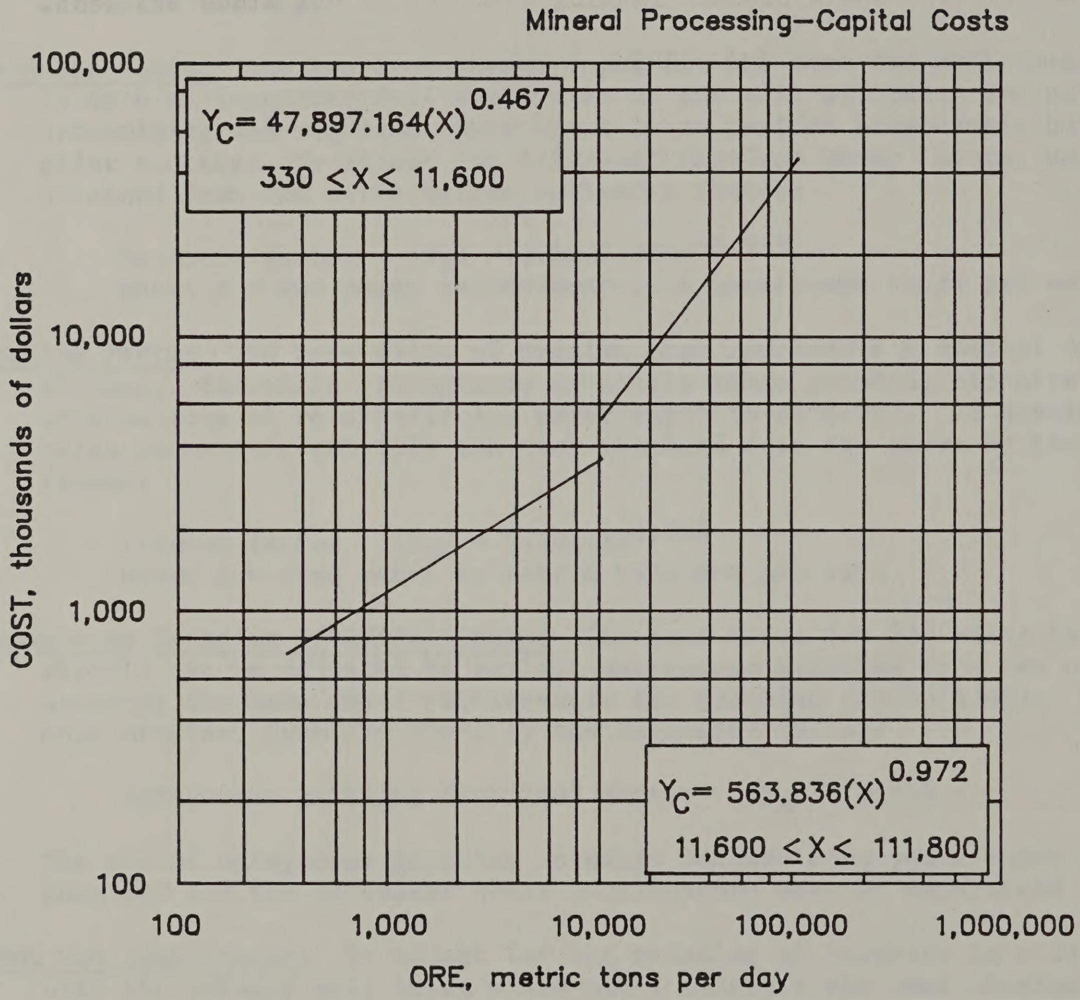
Iron ore (SAG) factor $(F_I) = 1.24$

The power requirements for SAG milling the taconite ore was taken as 21.5 hp•h/mt. The SAG mill product is 40% minus 325 mesh.

Iron Ore (Autogenous) Factor To adjust for the grinding of taconite in a two-stage circuit with the primary mill being an autogenous mill, multiply the cost obtained from the curve by the following factor:

Iron ore (autogenous) factor (F_O) = 1.95

The power requirement was set at 28 hp·h/mt and the autogenous mill product at 100% minus 16 mesh.



6.1.2.2. Semiautogenous grinding

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.2. COMMINUTION

6.1.2.3. RAYMOND MILL GRINDING

The capital cost for Raymond mill grinding is for the acquisition and installation of equipment needed to process barite. The Raymond mill circuit includes feed storage, a complete packaged Raymond mill unit, and product conveying. Included in the Raymond mill package is a Raymond roller mill, whizzer separator, fan, cyclone, cyclone valve, and vent baghouse. The circuit can process barite with a maximum lump size of 3/4 in (1.9 cm) and a product ranging from 70% to 99% minus 325 mesh.

BASE CURVE

The total capital cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of ore per day. The curve is valid for operations between 115 and 1,290 mtpd, operating two shifts per day. The curve includes all costs associated with the acquisition of the necessary bins, mills, cyclones, fans, and conveyors. The base curve is for grinding dry barite to a final product size of 90% minus 325 mesh. The mill requirement is based on 12.2 hp·h/mt.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	13.0%
Construction supply cost.....	3.0%
Purchased equipment cost.....	82.9%
Transportation cost..........	1.1%

The total capital cost is $(Y_C) = 5{,}509.259(X)^{0.792}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 716.204(X)^{0.792}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 165.278(X)^{0.792}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 4{,}672.777(X)^{0.792}$

ADJUSTMENT FACTORS

<u>Grind Factor</u> The capacity of the mill is very dependent on the required final product size distribution. To adjust for a final product other than 90% minus 325 mesh, multiply the cost obtained from the curve by the following factor:

Grind factor $(F_G) = (G/90)^{2.036}$
where G = new grind percentage, expressed as cumulative percent passing 325 mesh.

<u>Hardness Factor</u> Barite ores vary widely in the amount of power required to process a unit weight to a particular size. No means of estimating the required power is available, short of having the vendor treat a given sample. Given the required mill power per metric ton, multiply the cost obtained from the curve by the following factor:

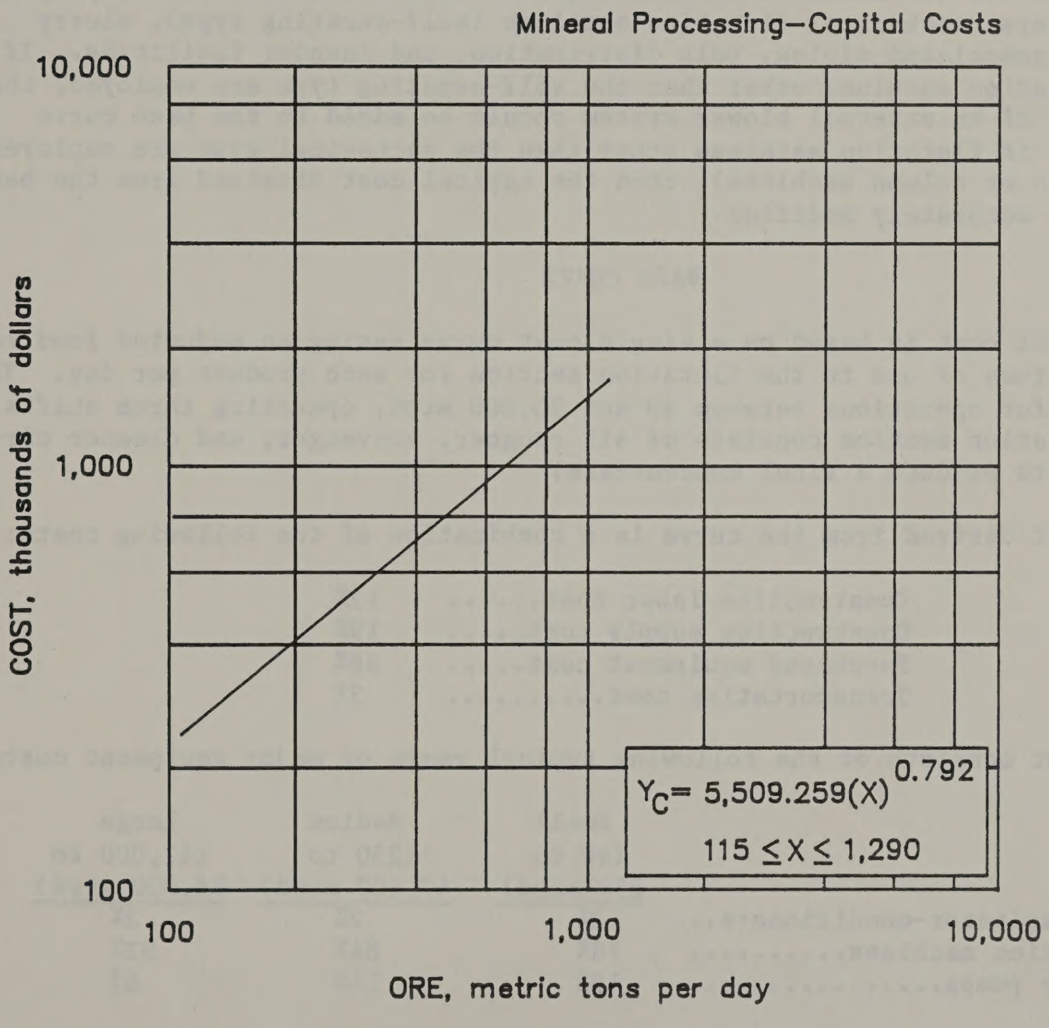
Hardness factor $(F_H) = (12.200/H)^{-0.794}$
where H = new estimated power required, in horsepower hours per metric ton.

Flash Drying Factor The base curve assumes grinding without drying in the mill. Should flash drying be incorporated in the mill design, multiply the cost obtained from the curve by the following factor:

Flash drying factor $(F_F) = 1.2$

Potash Factor The costs can be adjusted for grinding potash (langbeinite) by multiplying the cost obtained from the curve by the following factor:

Potash factor $(F_P) = 1.204$



6.1.2.3. Raymond mill grinding

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.3. BENEFICIATION

6.1.3.1. FLOTATION

The cost curve in this section is based on flotation operations that produce a single concentrate product. However, for operations that produce multiple concentrate products, costs can be estimated by reapplying the curve for each product, making the appropriate input tonnage reduction before each reapplication.

The capital cost for flotation covers the acquisition and installation of pulp agitator-conditioners, mechanical flotation machines (self-aerating type), slurry pumps, and any associated piping, pulp distribution, and launder facilities. If mechanical flotation machines other than the self-aerating type are employed, the additional cost of an external blower system should be added to the base curve cost. However, if flotation machines other than the mechanical type are employed (e.g., pneumatic or column machines), then the capital cost obtained from the base curve cannot be accurately modified.

BASE CURVE

The total capital cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of ore to the flotation section for each product per day. The curve is valid for operations between 40 and 95,000 mtpd, operating three shifts per day. Each flotation section consists of all rougher, scavenger, and cleaner circuits required to produce a final concentrate.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	12%
Construction supply cost.....	19%
Purchased equipment cost.....	66%
Transportation cost..........	3%

The capital cost consists of the following typical range of major equipment costs:

	Small (40 to 250 mtpd)	Medium (250 to 47,600 mtpd)	Large (47,000 to 95,000 mtpd)
Pulp agitator-conditioners..	12%	2%	2%
Flotation machines..........	78%	84%	92%
Slurry pumps................	10%	14%	6%

The total capital cost is $(Y_{C\ SMALL}) = 7{,}813.781(X)^{0.600}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_{L\ SMALL}) = 937.654(X)^{0.600}$

(S) <u>Construction Supply Cost</u> $(Y_{S\ SMALL}) = 1{,}484.618(X)^{0.600}$

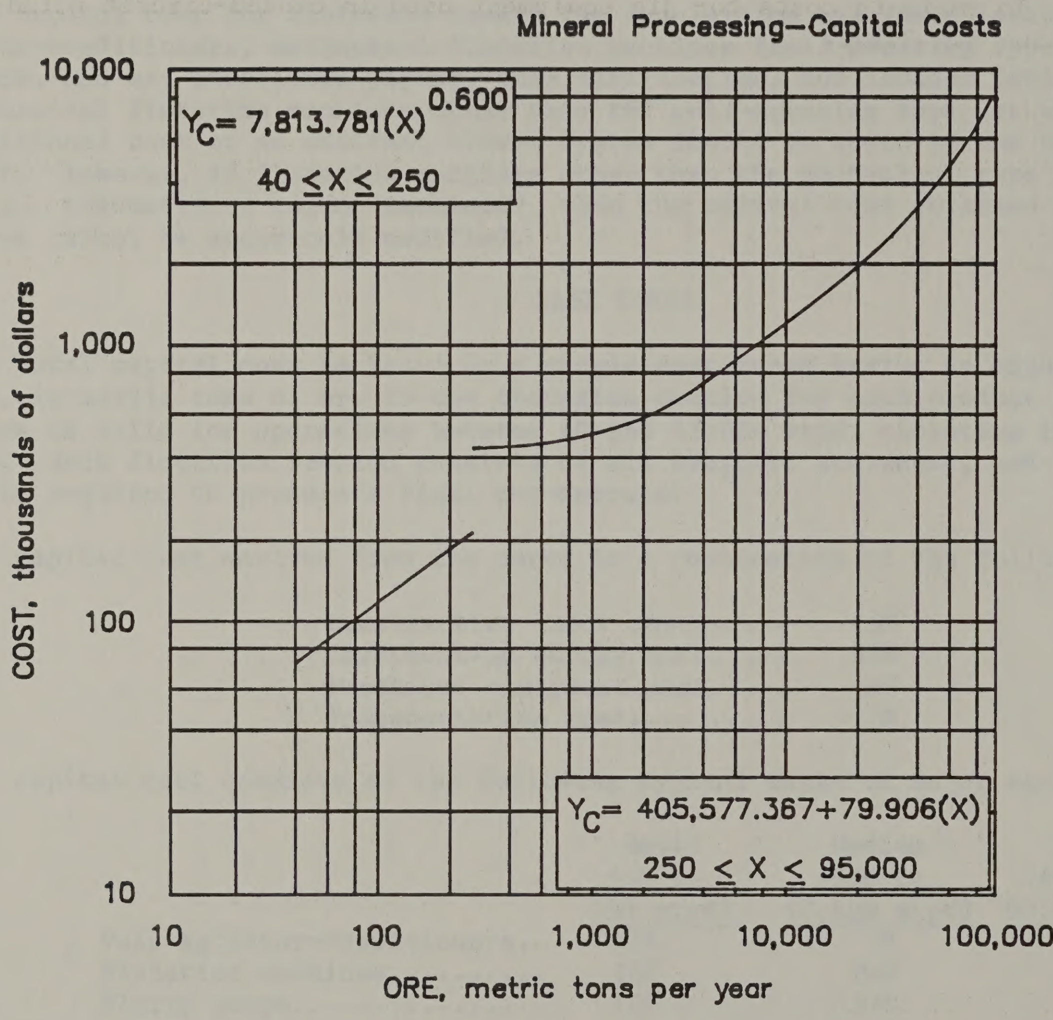
(E) <u>Purchased Equipment Cost</u> $(Y_{E\ SMALL}) = 5{,}391.509(X)^{0.600}$

The total capital cost is ($Y_{C\ MEDIUM/LARGE}$) = 405,577.367+79.906(X) and is distributed as follows:

(L) Construction Labor Cost ($Y_{L\ MEDIUM/LARGE}$) = 48,669.283+9.589(X)

(S) Construction Supply Cost ($Y_{S\ MEDIUM/LARGE}$) = 77,059.699+15.182(X)

(E) Purchased Equipment Cost ($Y_{E\ MEDIUM/LARGE}$) = 279,848.385+55.135(X)



6.1.3.1. Flotation

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.3. BENEFICIATION

6.1.3.2.1. GRAVITY SEPARATION JIGS

Costs are primarily for the acquisition and installation of jigs, vibrating and trommel screens, pumps, and surge bins. The cost curves are most applicable to barite, gold placer, diamond, and chromite processing operations. Use of the curves for other types of mineral deposits, or for unique treatment systems, may give less accurate results. To estimate costs for jig equipment used in closed-circuit grinding, refer to section 6.1.3.2.2.

BASE CURVE

The total capital cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of ore to the jig circuit per day. The curve is valid for operations between 400 and 10,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition, freight, and installation of equipment.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	6%
Construction supply cost.....	14%
Purchased equipment cost.....	79%
Freight cost.................	1%

A typical breakdown of the major cost components is

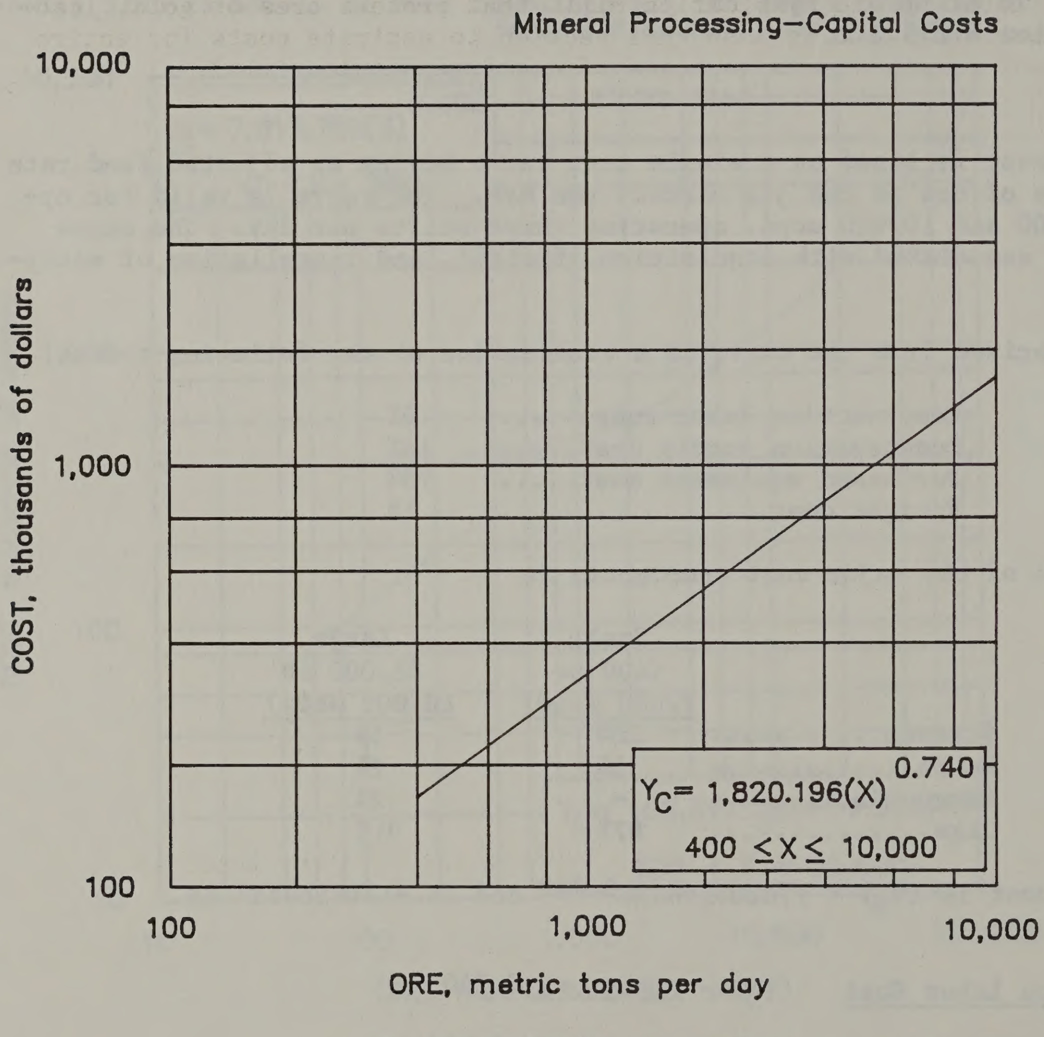
	Small (400 to 2,000 mtpd)	Large (2,000 to 10,000 mtpd)
Screens...........	10%	5%
Pumps.............	3%	2%
Surge bins........	-	2%
Jigs..............	87%	91%

The total capital cost is $(Y_C) = 1,820.196(X)^{0.740}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 109.212(X)^{0.740}$

(S) Construction Supply Cost $(Y_S) = 254.827(X)^{0.740}$

(E) Purchased Equipment Cost $(Y_E) = 1,456.157(X)^{0.740}$



6.1.3.2.1. Gravity separation
JIGS

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.3. BENEFICIATION

6.1.3.2.2. GRAVITY SEPARATION
JIGS IN CLOSED-CIRCUIT GRINDING

Costs are for the acquisition and installation of jigs, pumps, and screens used in closed-circuit grinding. This is an accessory process used prior to other forms of treatment, such as flotation or cyanidation, where coarse material, or large particles, would not be recovered. Jigs in closed-circuit grinding are most commonly employed in small flotation and cyanidation mills that process ores of gold, lead-silver-zinc, and fluorspar. Do not use this section to estimate costs for entire circuits of jigs that process large tonnages of ore (see section 6.1.3.2.1.).

BASE CURVE

The total cost is based on a single cost curve having an adjusted feed rate (X), in metric tons ore to the jig circuit per day. The curve is valid for operations between 25 and 700 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition, freight, and installation of equipment.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	5%
Construction supply cost.....	10%
Purchased equipment cost.....	84%
Freight cost	1%

A typical breakdown of the major cost components is

	Small (25 to 350 mtpd)	Large (350 to 700 mtpd)
Screens...........	47%	27%
Pumps.............	9%	5%
Jigs..............	44%	68%

The total capital cost is $(Y_C) = 35{,}135.962e^{0.0007(X)}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 1{,}756.798e^{0.0007(X)}$

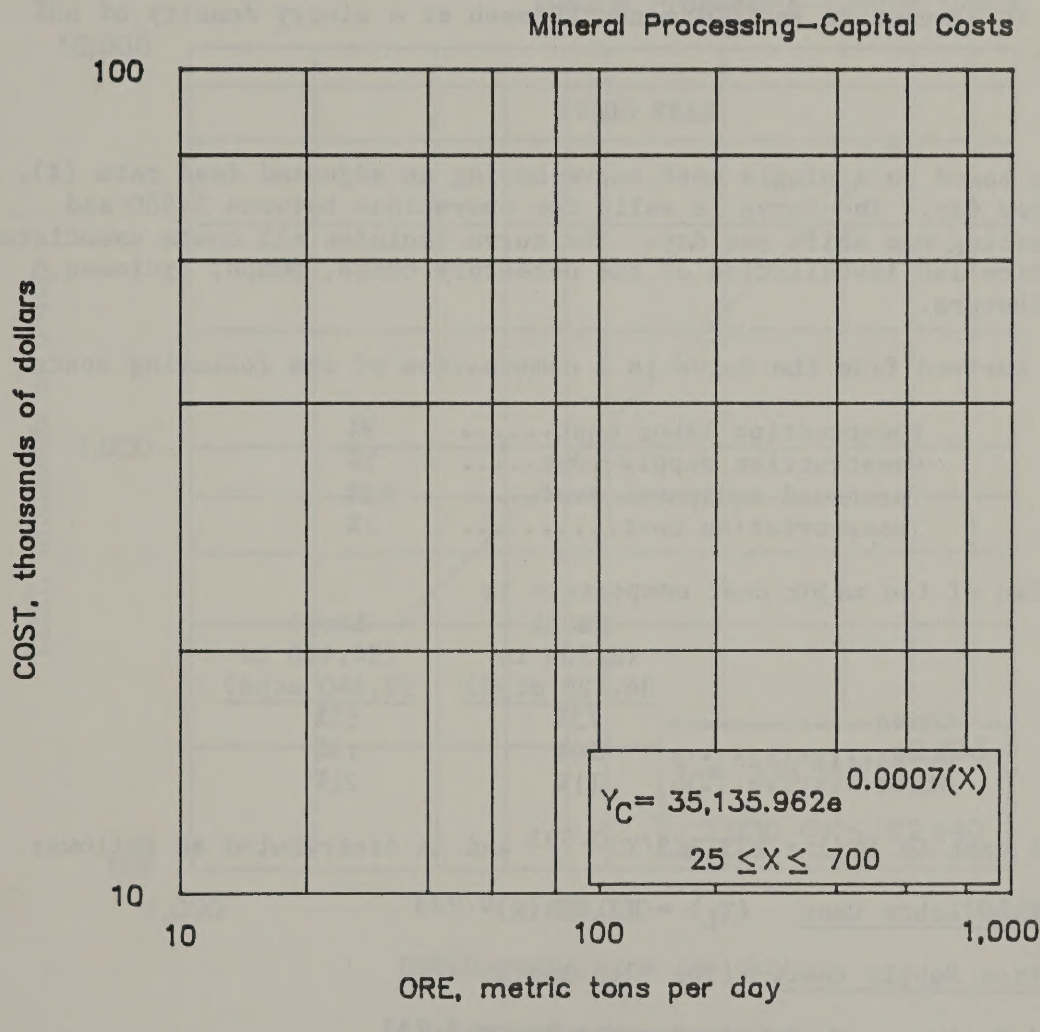
(S) Construction Supply Cost $(Y_S) = 3{,}513.596e^{0.0007(X)}$

(E) Purchased Equipment Cost $(Y_E) = 29{,}865.568e^{0.0007(X)}$

ADJUSTMENT FACTOR

Screen Factor The curve includes costs for screens; however, in many instances, screens are not used with this type of jig treatment. If screens are not used, multiply the cost obtained from curve by the following equation:

Screen factor $(F_S) = 0.495+0.00296(X)$
where X = ore to the jig circuit, in metric tons per day.



6.1.3.2.2. Gravity separation
JIGS IN CLOSED CIRCUIT GRINDING

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.3. BENEFICIATION

6.1.3.2.3. GRAVITY SEPARATION REICHERT CONES

The capital cost for gravity separation (Reichert cone) is for the acquisition and installation of equipment needed to process the ore containing heavy minerals. The Reichert cone circuit includes rougher, scavenger, cleaner and recleaner cones. The Reichert cone circuit can process ores containing 0.15 to 5.0% heavy minerals and yield a product containing a minimum of 80% heavy minerals. The feed for the Reichert circuit is assumed to be 100% minus 10 mesh at a slurry density of 60% solids by weight.

BASE CURVE

The total cost is based on a single cost curve having an adjusted feed rate (X), in metric tons ore per day. The curve is valid for operations between 2,900 and 52,440 mtpd, operating one shift per day. The curve includes all costs associated with the acquisition and installation of the necessary cones, pumps, cyclones, sumps, and distributors.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	9%
Construction supply cost.....	7%
Purchased equipment cost.....	83%
Transportation cost..........	1%

A typical breakdown of the major cost components is

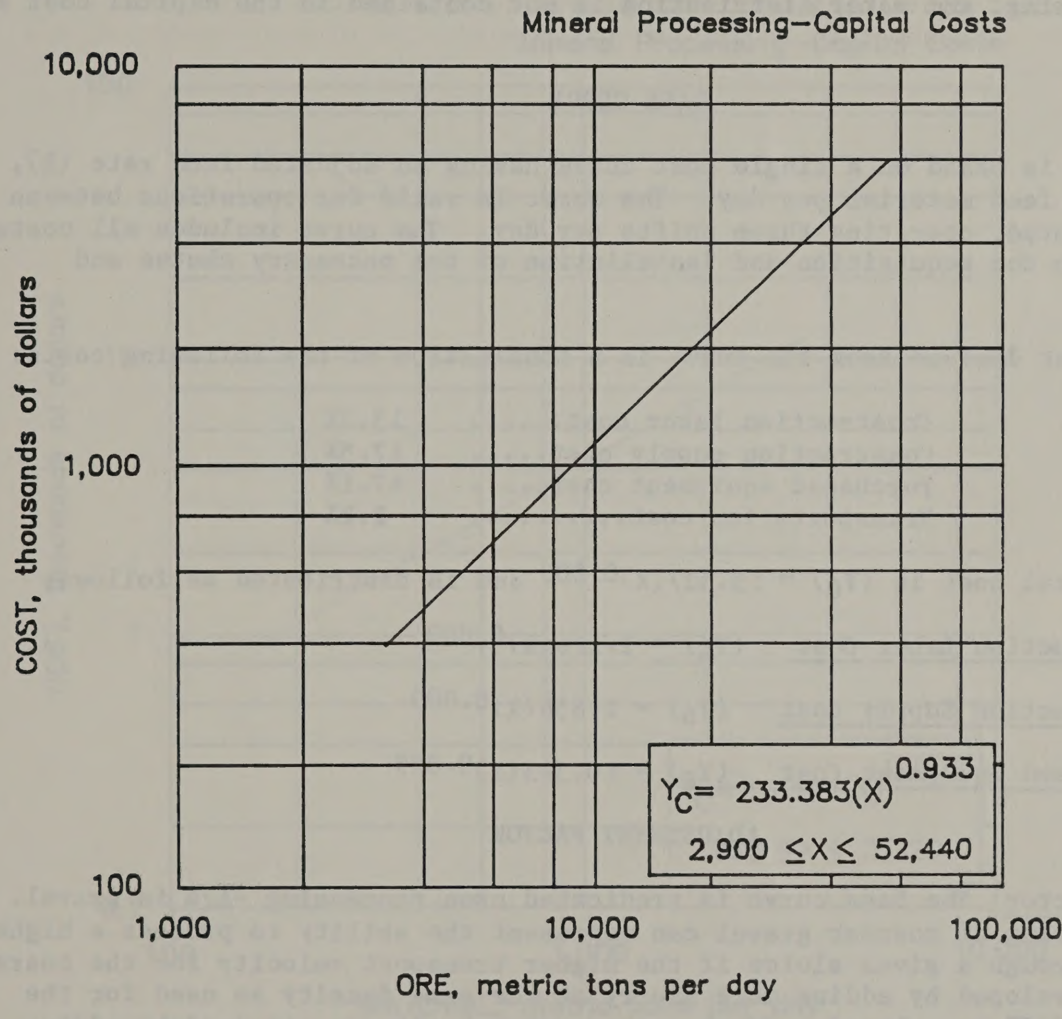
	Small (2,900 to 34,420 mtpd)	Large (34,420 to 52,440 mtpd)
Cones.............	73%	65%
Pumps.............	16%	14%
Other.............	11%	21%

The total capital cost is $(Y_C) = 233.383(X)^{0.933}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 23.338(X)^{0.933}$

(S) Construction Supply Cost $(Y_S) = 16.337(X)^{0.933}$

(E) Purchased Equipment Cost $(Y_E) = 193.708(X)^{0.933}$



6.1.3.2.3. Gravity separation
REICHERT CONES

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.3. BENEFICIATION

6.1.3.2.4. GRAVITY SEPARATION SLUICING

The capital cost for sluicing is for the acquisition and installation of equipment needed to process gravels containing gold or valuable heavy minerals. The feed for the sluicing operation is a slurry that has been prepared by screening with either a vibrating or trommel screen, or by hydraulic mining. The cost associated with washing, screening, and water distribution is not contained in the capital cost for sluicing.

BASE CURVE

The total cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of feed material per day. The curve is valid for operations between 160 and 3,320 mtpd, operating three shifts per day. The curve includes all costs associated with the acquisition and installation of the necessary chutes and sluices.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	13.2%
Construction supply cost.....	17.5%
Purchased equipment cost.....	67.1%
Transportation cost..........	2.2%

The total capital cost is $(Y_C) = 15.327(X)^{0.809}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 2.176(X)^{0.809}$

(S) Construction Supply Cost $(Y_S) = 2.836(X)^{0.809}$

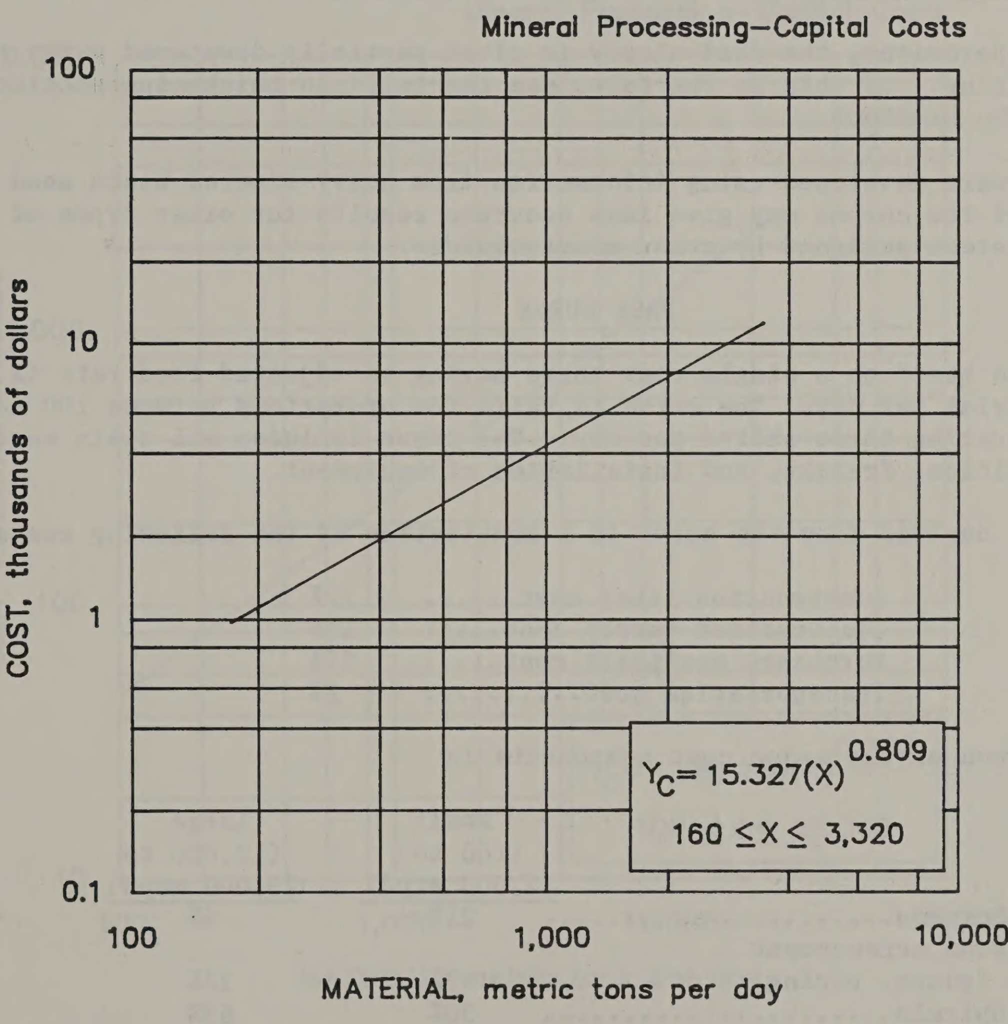
(E) Purchased Equipment Cost $(Y_E) = 10.315(X)^{0.809}$

ADJUSTMENT FACTOR

Gravel Size Factor The base curve is predicated upon processing -1/4 in gravel. The processing of coarser gravel can represent the ability to process a higher tonnage through a given sluice if the higher transport velocity for the coarser rock is developed by adding more slurry at the same density as used for the base case (15% by volume). If the transport velocity is attained by adding more water to the same tonnage as treated by the 1/4 in sluice, then no adjustment is needed.

To adjust for adding more slurry to transport the larger gravel, multiply the cost obtained from the curve by the following factor:

Gravel size factor $(F_R) = 0.316(R)^{-0.554}$
where R = radius of the top size gravel to be processed, in inches.



6.1.3.2.4. Gravity separation
SLUICING

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.3. BENEFICIATION

6.1.3.2.5. GRAVITY SEPARATION SPIRALS

Costs are for the acquisition and installation of spiral concentrating equipment. Major items of equipment are spiral concentrators, screens, pumps, and slurry distributors. This cost curve does not include equipment for slurry preparation, dewatering, drying, or other types of gravity concentration. To incorporate these other processes, use the appropriate sections of this handbook.

For beach sand operations, the feed slurry is often partially dewatered prior to spiral concentrating. If this is the case, use the tailings thickening section, 6.1.4.1.2., of the handbook.

The cost curves were developed using information from heavy-mineral beach sand operations. Use of the curves may give less accurate results for other types of deposits or for systems designed by other manufacturers.

BASE CURVE

The total cost is based on a single cost curve having an adjusted feed rate (X), in metric tons material per day. The curve is valid for operations between 100 and 25,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition, freight, and installation of equipment.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	27%
Construction supply cost.....	13%
Purchased equipment cost.....	59%
Transportation cost..........	1%

A typical breakdown of the major cost components is

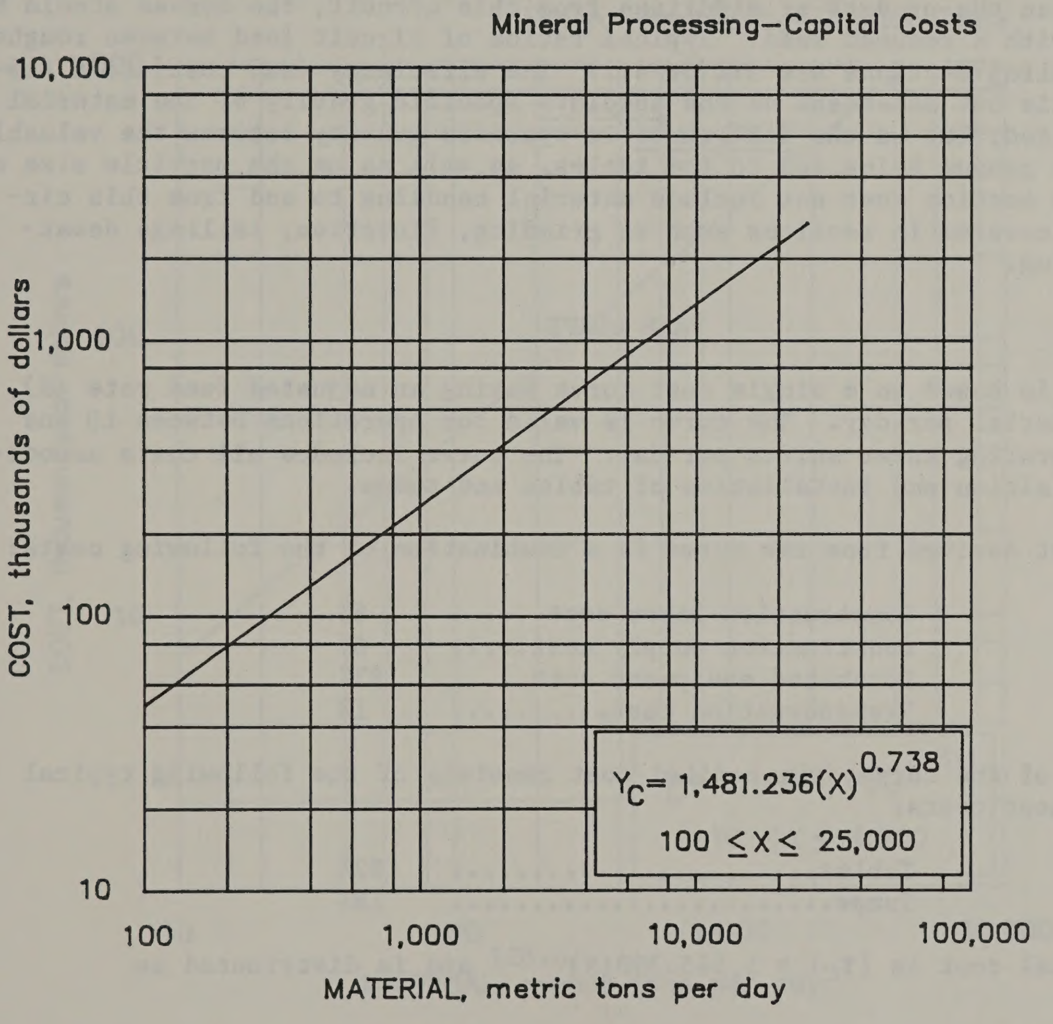
	Small (100 to 12,000 mtpd)	Large (12,000 to 25,000 mtpd)
Screens.....................	21%	8%
Feed arrangement (pumps, piping, etc.).......	49%	27%
Spirals.....................	30%	65%

The total capital cost is $(Y_C) = 1,481.236(X)^{0.738}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 385.121(X)^{0.738}$

(S) Construction Supply Cost $(Y_S) = 192.561(X)^{0.738}$

(E) Purchased Equipment Cost $(Y_E) = 903.554(X)^{0.738}$



6.1.3.2.5. Gravity separation
SPIRALS

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.3. BENEFICIATION

6.1.3.2.6. GRAVITY SEPARATION
TABLES

The capital cost of concentrating tables includes the acquisition and installation of equipment to concentrate by gravity, ground, or finely crushed, ores or concentrates of copper, gold, lead, potash, tungsten, tin, zinc, or graphite. This section covers the total cost of rougher tables only. If the handbook user desires to re-table or clean the product or middlings from this circuit, the curves should be entered again with a reduced feed. Typical ratios of circuit feed between rougher and cleaner tabling sections are 3:1 or 4:1. The efficiency (and cost) of a tabling operation is not dependent on the absolute specific gravity of the material being concentrated, but on the difference in specific gravity between the valuable mineral and the gangue being fed to the tables, as well as on the particle size of the feed. This section does not include material handling to and from this circuit, which is covered in sections such as grinding, flotation, tailings dewatering, and drying.

BASE CURVE

The total cost is based on a single cost curve having an adjusted feed rate (X), in metric tons material per day. The curve is valid for operations between 10 and 4,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition and installation of tables and pumps.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	6%
Construction supply cost.....	6%
Purchased equipment cost.....	87%
Transportation cost..........	1%

Over the range of the curve, the capital cost consists of the following typical ratio of equipment costs:

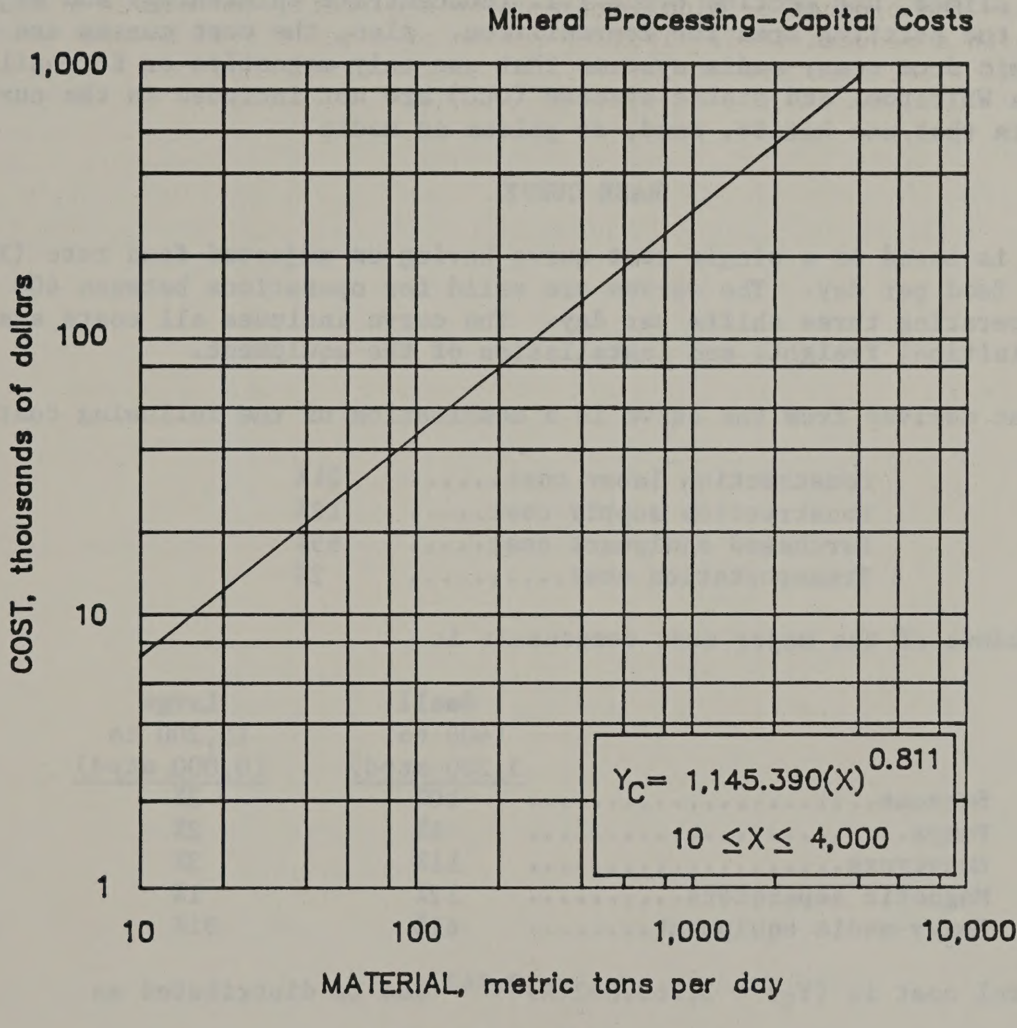
Tables.......................	82%
Pumps........................	18%

The total capital cost is $(Y_C) = 1,145.390(X)^{0.811}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 68.723(X)^{0.811}$

(S) Construction Supply Cost $(Y_S) = 68.723(X)^{0.811}$

(E) Purchased Equipment Cost $(Y_E) = 1,007.944(X)^{0.811}$



6.1.3.2.6. Gravity separation
TABLES

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.3. BENEFICIATION

6.1.3.3. HEAVY-MEDIA SEPARATION

Costs are for acquisition and installation of the heavy-media circuit equipment. Major items of equipment are heavy-media drums, screens, conveyors, demagnetizing coils, densifiers, pumps, and magnetic separators. The cost curves are based on operations that are low in slimes; consequently, thickeners for medium cleaning are not included in the costs. To incorporate thickeners within the circuit to handle ore containing slimes, use section 6.1.4.1.1. (concentrate thickening) and adjust the cost using the settling area for ferrosilicon. Also, the cost curves are derived for dynamic drum heavy-media systems that use only magnetite or ferrosilicon as media. Dyna Whirlpool and static systems (OCC) are not included in the curves, nor are circuits that use barite, sand, or galena as media.

BASE CURVE

The total cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of feed per day. The curves are valid for operations between 400 and 10,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition, freight, and installation of the equipment.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	21%
Construction supply cost.....	12%
Purchased equipment cost.....	65%
Transportation cost..........	2%

A typical breakdown of the major cost components is

	Small (400 to 5,200 mtpd)	Large (5,200 to 10,000 mtpd)
Screens......................	10%	3%
Pumps........................	6%	2%
Conveyors....................	11%	3%
Magnetic separators..........	12%	1%
Heavy-media equipment........	61%	91%

The total capital cost is $(Y_C) = 3{,}763.892(X)^{0.742}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 790.417(X)^{0.742}$

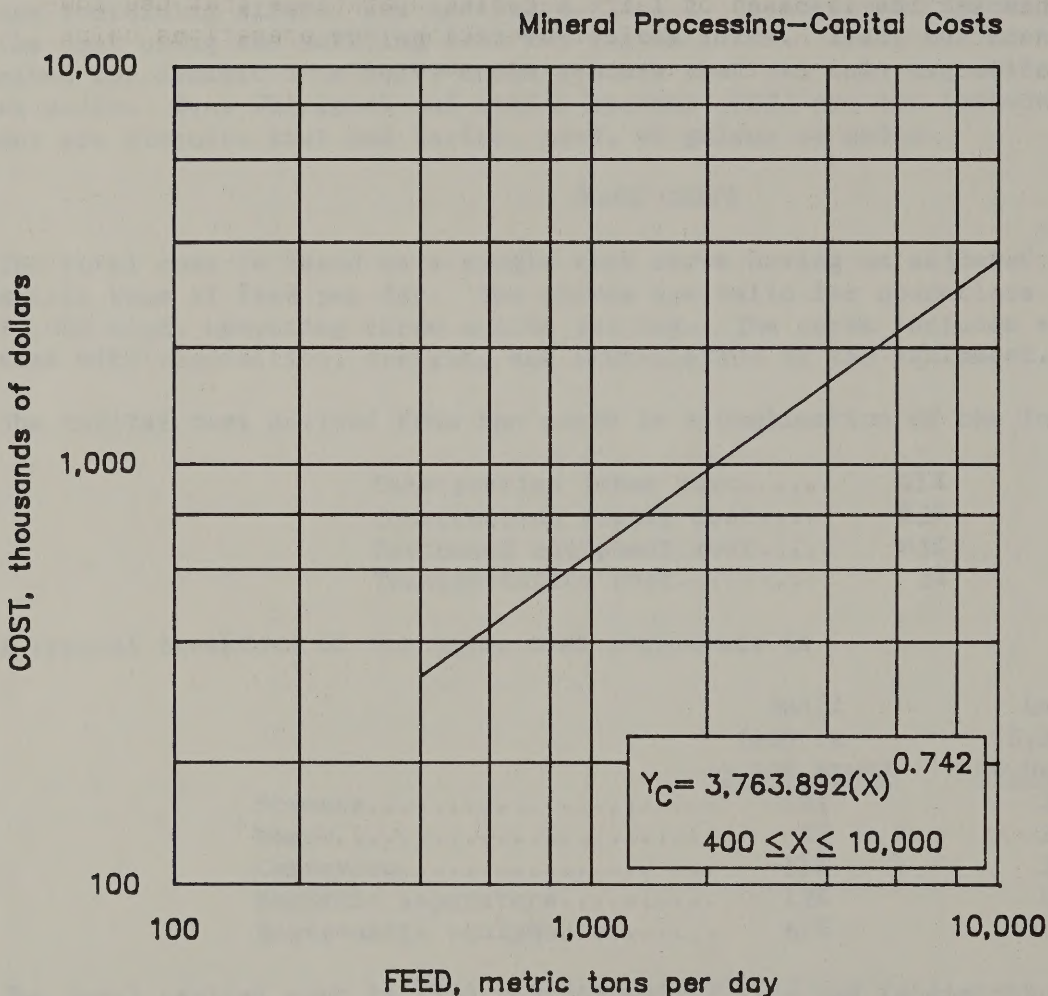
(S) Construction Supply Cost $(Y_S) = 451.667(X)^{0.742}$

(E) Purchased Equipment Cost $(Y_E) = 2{,}521.808(X)^{0.742}$

ADJUSTMENT FACTOR

Cone Separation Factor If heavy-media cone separators are to be used, multiply the cost obtained from the curve by the following factor:

Cone separation factor $(F_C) = 0.9$



6.1.3.3. Heavy—media separation

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.3. BENEFICIATION

6.1.3.4.1. MAGNETIC SEPARATION

The costs are for acquisition and installation of low-intensity wet magnetic separation equipment. Major items include magnetic separators, screens, slurry pumps, and miscellaneous materials. The curve does not include costs for dewatering, desliming, tramp-iron removal, or grinding and regrinding. If any of these processes are to be included within the circuit, the appropriate section of this handbook should be used. This section is based on large taconite operations that use low-intensity, wet magnetic separation. For smaller operations, or operations using other types of magnetic processing, the curve is less accurate.

BASE CURVE

The total cost is based on a single cost curve having a daily adjusted feed rate (X), in metric tons feed per day. The curve is valid for operations between 4,000 and 80,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition, freight, and installation of the equipment.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	2%
Purchased equipment cost.....	96%
Transportation cost..........	2%

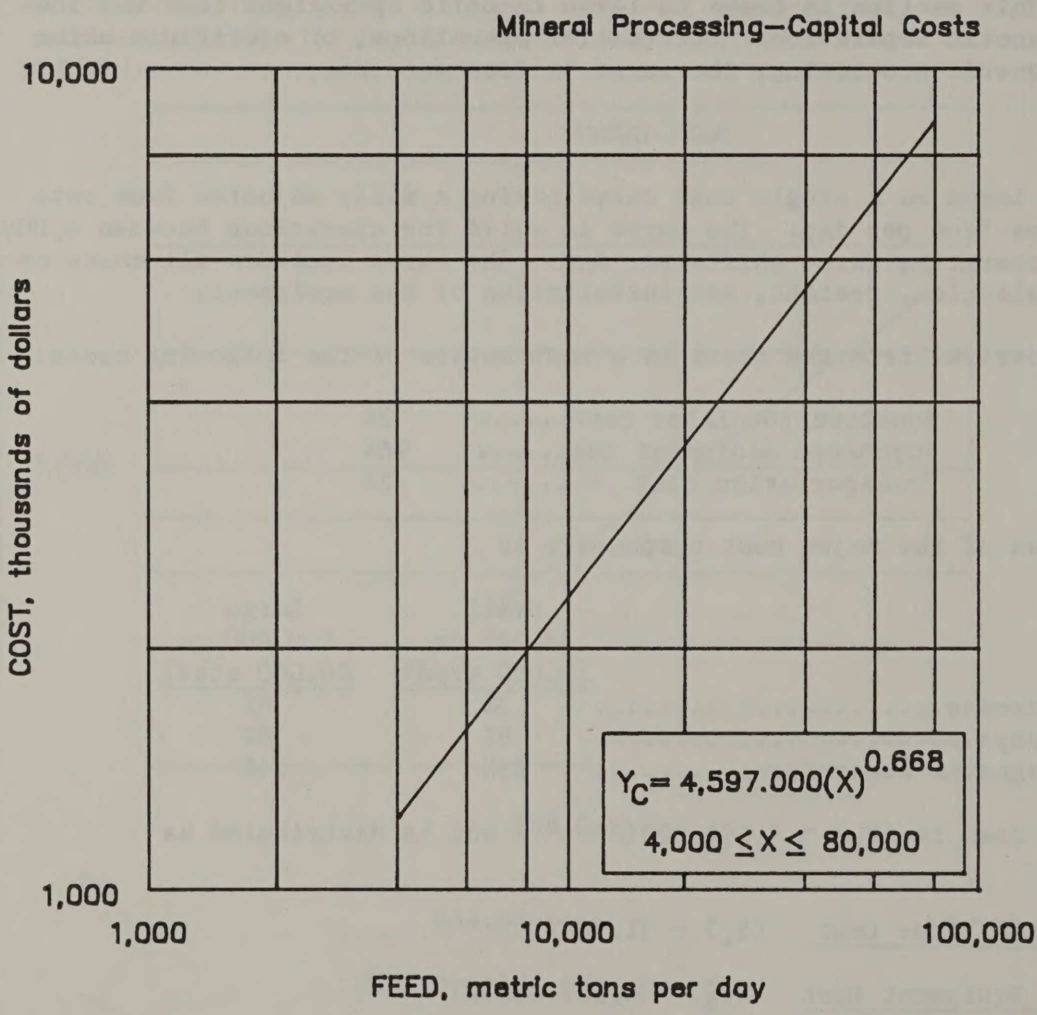
A typical breakdown of the major cost components is

	Small (4,000 to 10,000 mtpd)	Large (10,000 to 80,000 mtpd)
Screens......................	3%	8%
Pumps........................	8%	8%
Magnetic separators..........	89%	84%

The total capital cost is $(Y_C) = 4,597.000(X)^{0.668}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 91.940(X)^{0.668}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 4,505.060(X)^{0.668}$



6.1.3.4.1. Magnetic separation

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.3. BENEFICIATION

6.1.3.4.2. HIGH-INTENSITY MAGNETIC SEPARATION WET (WHIMS)

The capital cost for high-intensity magnetic separation is for the acquisition and installation of equipment needed to produce a magnetic concentrate from an ore or concentrate. The high-intensity magnetic separation unit operation has been divided into two sections, wet and dry. For both sections the cost includes the cost for the magnetic separator and the necessary materials handling equipment. The total cost is based on a single cost curve having an adjusted feed rate (X), in metric tons dry feed to the magnetic separation circuit per day. The curve is valid for operations between 2,100 and 47,000 mtpd, operating three shifts per day.

BASE CURVE

The base curve is predicated on processing a hematite bearing ore through wet high-intensity magnetic separators (WHIMS). The base curve assumes a three-shift-per-day operation with an availability of 95%. The base curve is for a single stage of magnetic separation. The total cost includes the costs associated with the acquisition and installation of the oversize removal screens, feed pumps, feed distributors, tailings collection, middling collection and final product collection.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	2.3%
Construction supply cost...	1.5%
Purchased equipment cost...	95.7%
Transportation cost........	0.5%

The total capital cost is $(Y_{C\ WET}) = 515.411(X)^{0.970}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_{L\ WET}) = 11.855(X)^{0.970}$

(S) <u>Construction Supply Cost</u> $(Y_{S\ WET}) = 10.308(X)^{0.970}$

(E) <u>Purchased Equipment Cost</u> $(Y_{E\ WET}) = 493.248(X)^{0.970}$

ADJUSTMENT FACTORS

<u>Additional Cleaner Stage Factor</u> To produce a higher quality product, a cleaner stage may be added to the base curves. To adjust for the addition of a cleaner stage, multiply the cost obtained from the curve by the following factor:

Additional cleaner stage factor $(F_C) = 1.24$

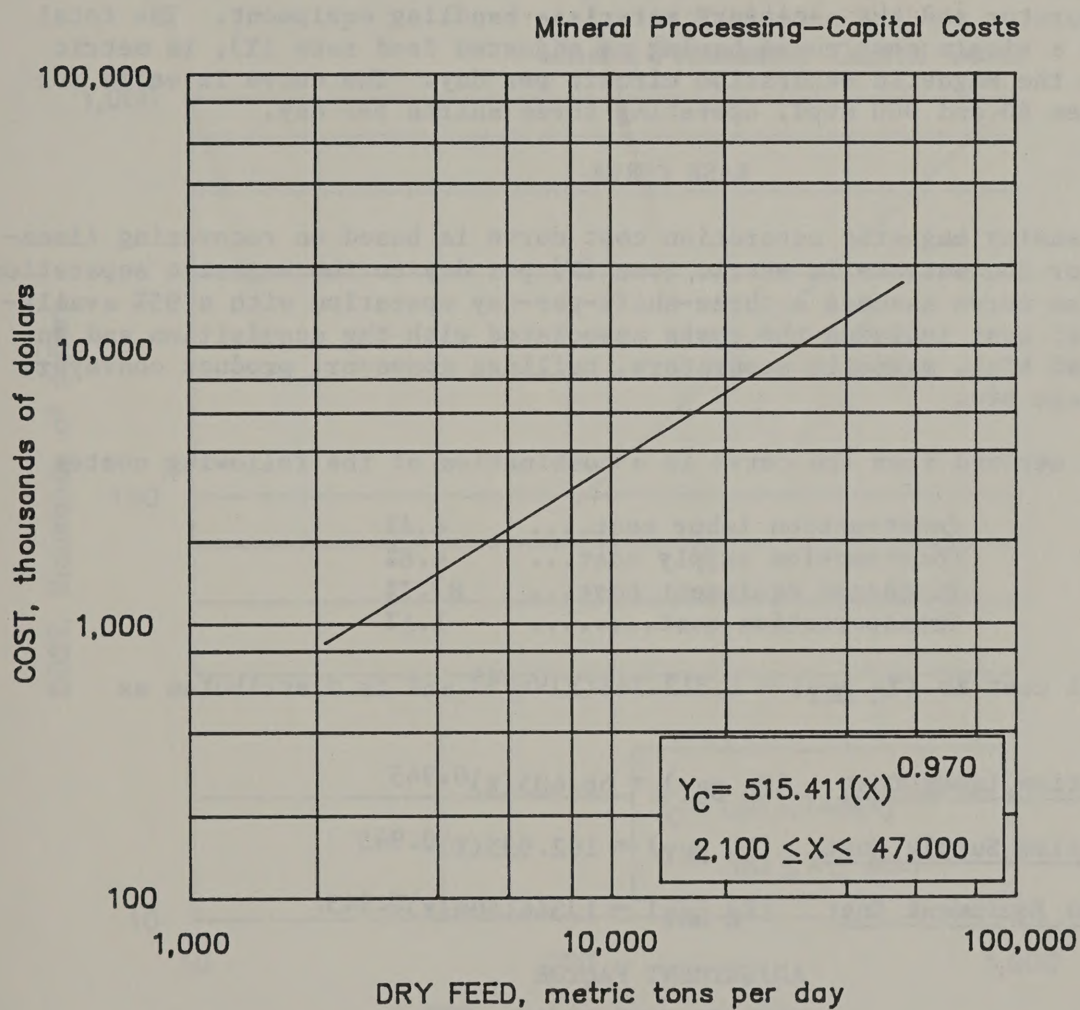
<u>Feed Rate Factor</u> The WHIMS can be used as a scavenger rather than a primary recovery device. The maximum feed that a WHIMS can handle is a function of mineralogy, ore size distribution, slurry density, magnetic properties of solids. The base case assumes a feed rate of 115 mtph to a double rotor, 3.17 m wide WHIMS.

To adjust for different feed rates, the base curve should be multiplied times the following factor:

Feed rate factor $(F_R) = 97.867(R)^{-0.966}$
where R = new feed rate, in metric tons per hour.

While there are no hard and fast guidelines for feed rates for different commodities, the following can be utilized as approximate guidelines:

Commodity	mtph
Gold Tailings..................	70
Chromite......................	50
Iron Ore Tailings.............	90



6.1.3.4.2. High intensity magnetic separation—wet (WHIMS)

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.3. BENEFICIATION

6.1.3.4.3. HIGH-INTENSITY MAGNETIC SEPARATION DRY

The capital cost for high-intensity magnetic separation is for the acquisition and installation of equipment needed to produce a magnetic concentrate from an ore or concentrate. The high-intensity magnetic separation unit operation has been divided into two sections, wet and dry. For both sections the cost includes the cost for the magnetic separator and the necessary materials handling equipment. The total cost is based on a single cost curve having an adjusted feed rate (X), in metric tons dry feed to the magnetic separation circuit per day. The curve is valid for operations between 80 and 900 mtpd, operating three shifts per day.

BASE CURVE

The dry high-intensity magnetic separation cost curve is based on recovering ilmenite from an ore or concentrate in metric tons (X) per day to the magnetic separation circuit. The base curve assumes a three-shift-per-day operation with a 95% availability. The total cost includes the costs associated with the acquisition and installation of feed bins, magnetic separators, tailings conveyor, product conveyor, and product storage bin.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	4.4%
Construction supply cost...	6.8%
Purchased equipment cost...	87.7%
Transportation cost........	1.1%

The total capital cost is $(Y_{C\ DRY}) = 1,513.748(X)^{0.945}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_{L\ DRY}) = 66.605(X)^{0.945}$

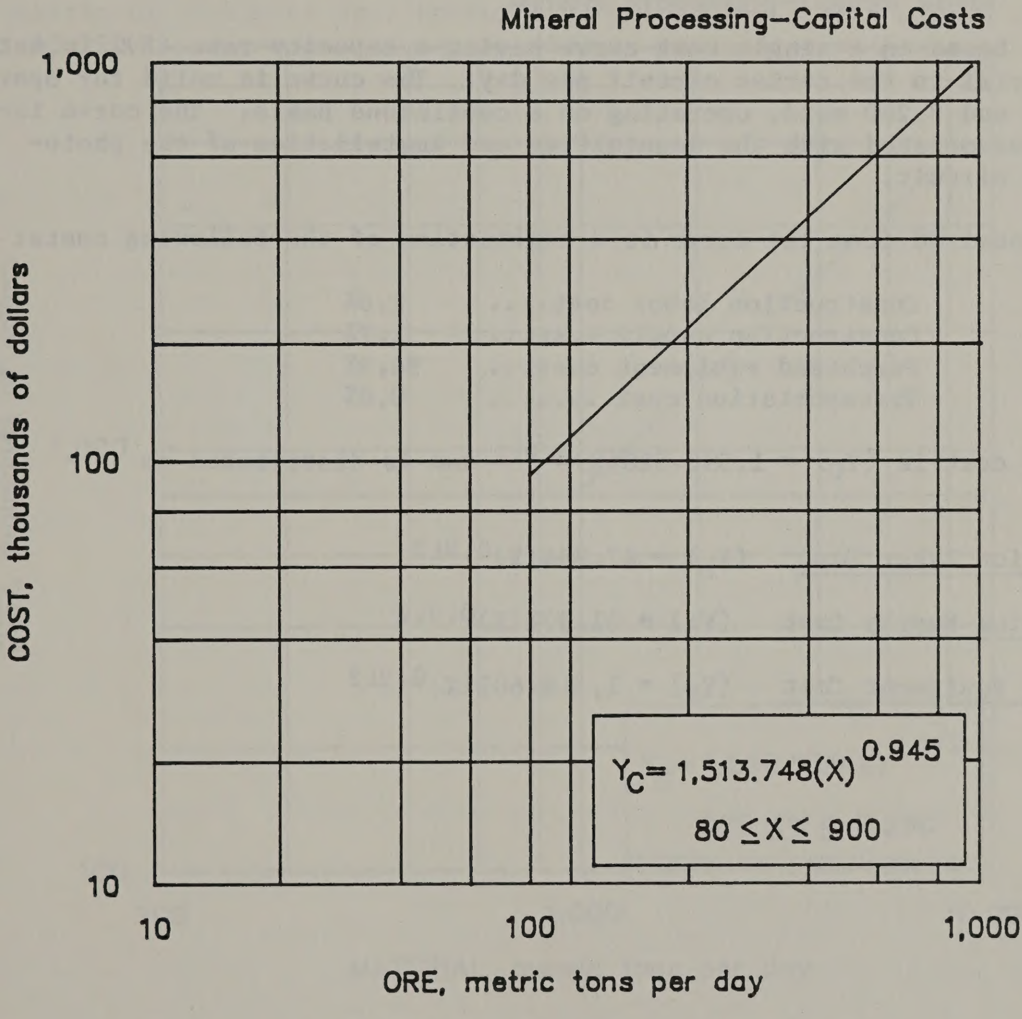
(S) <u>Construction Supply Cost</u> $(Y_{S\ DRY}) = 102.935(X)^{0.945}$

(E) <u>Purchased Equipment Cost</u> $(Y_{E\ DRY}) = 1,344.208(X)^{0.945}$

ADJUSTMENT FACTOR

<u>Feed Rate Factor</u> The base curve is based on feeding a high intensity induced roll separator at a feed rate of 25.8 kg/h per centimeter of roll length. The feed rate can vary from 9 to 179 kg/h per centimeter depending on the application. For the strategic commodities, the range is narrower at 18 to 55 kg/h per centimeter. To adjust for different feed rates, multiply the cost obtained from the curve by the following factor:

Feed rate factor $(F_R) = 21.437(F)^{-0.943}$
where F = new feed rate, in kilograms per hour per centimeter of roll length



6.1.3.4.3. High intensity magnetic separation—dry

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.3. BENEFICIATION

6.1.3.5. PHOTOMETRIC SEPARATION

The capital cost for photometric separation is for the acquisition and installation of equipment needed to separate economic minerals from waste, based on a visual difference between these components. The photometric separation circuit consists of photometric sorters and related equipment such as conveyors and air compressors.

BASE CURVE

The total cost is based on a single cost curve having a capacity rate (X), in metric tons of feed material to the sorter circuit per day. The curve is valid for operations between 925 and 7,280 mtpd, operating on a continuous basis. The curve includes all costs associated with the acquisition and installation of the photometric separation circuit.

The capital cost derived from the curve is a combination of the following costs:

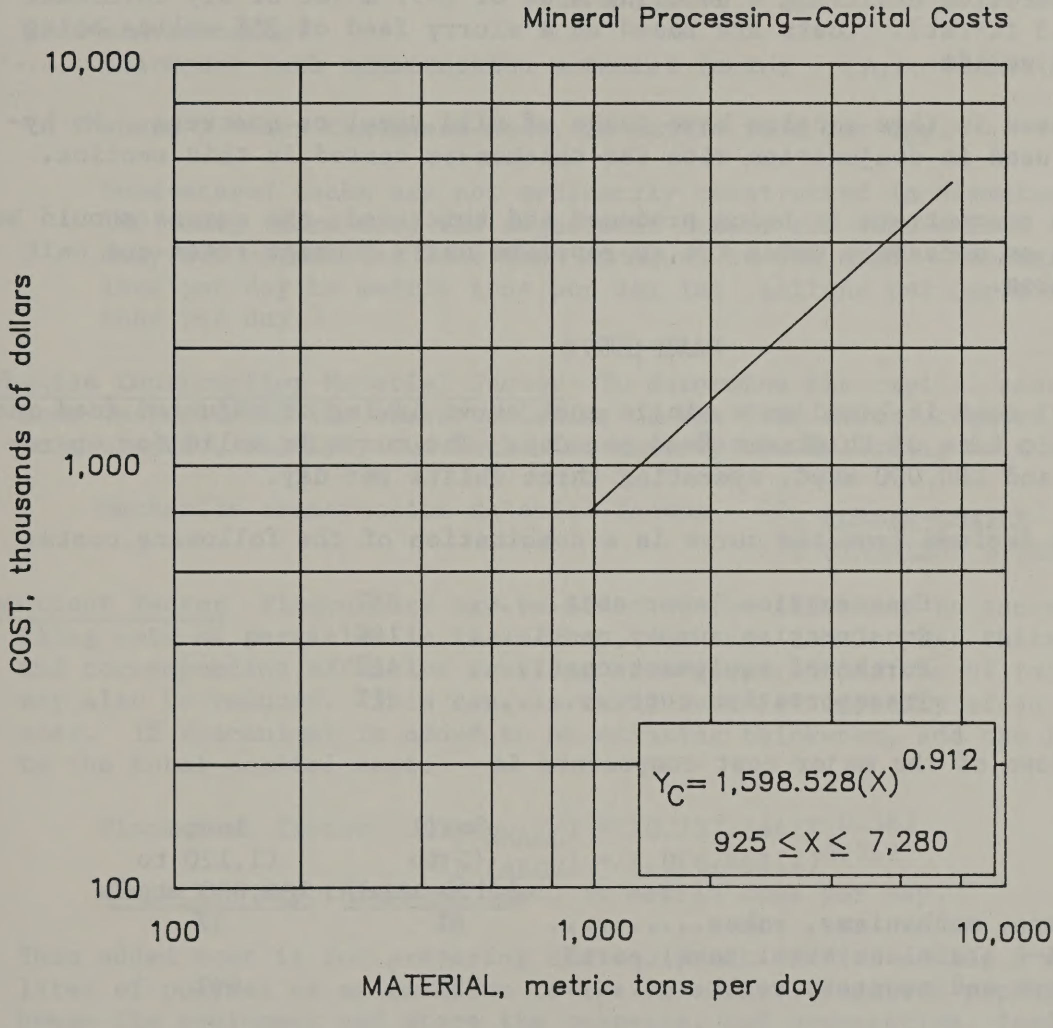
Construction labor cost....	2.6%
Construction supply cost...	1.7%
Purchased equipment cost...	94.9%
Transportation cost........	0.8%

The total capital cost is $(Y_C) = 1,598.528(X)^{0.912}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 47.956(X)^{0.912}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 31.971(X)^{0.912}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 1,518.602(X)^{0.912}$



6.1.3.5. Photometric separation

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.4. SOLID-LIQUID SEPARATION

6.1.4.1.1. SEDIMENTATION
CONCENTRATE THICKENING

The capital cost for concentrate thickening covers all earthwork, construction of tank, purchase and installation of pumps, drive mechanism, and rake. The curve does not apply to high capacity, tray, middling, or deep cone thickeners, or to clarifiers or counter-current decantation arrangements. The cost is based on a three-shift-per-day operation utilizing a settling area of 0.77 m^2/mt of dry thickener feed per day (7.5 ft^2/st). Costs are based on a slurry feed of 25% solids being thickened to 50% solids.

The thickeners used in this section have tanks of mild steel or concrete. No hydrocyclones are used in conjunction with the thickeners costed in this section.

If more than one concentrate is being produced and thickened, the curves should be entered as often as necessary using the appropriate daily tonnage rates and unit area settling rates.

BASE CURVE

The total capital cost is based on a single cost curve having an adjusted feed rate (X), in dry metric tons of thickener feed per day. The curve is valid for operations between 5 and 100,000 mtpd, operating three shifts per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	35%
Construction supply cost.....	18%
Purchased equipment cost.....	46%
Transportation cost..........	1%

A typical breakdown of the major cost components is

	Small (5 to 1,120 mtpd)	Large (1,120 to 100,000 mtpd)
Pumps, mechanisms, rakes..........	8%	1%
316-L stainless steel tank, earth work and concrete work...........	92%	99%

The total capital cost is $(Y_C) = 5{,}465.673(X)^{0.625}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 1{,}912.986(X)^{0.625}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 983.821(X)^{0.625}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 2{,}568.866(X)^{0.625}$

ADJUSTMENT FACTORS

Thickener Tank Construction Material Factor A diversity of construction methods and resulting materials of fabrication or concrete are used for thickener tanks. If mild steel or concrete is not used, multiply the supplies portion of the cost obtained from the curve by one of the following factors:

Mild steel with rubber-lining:
Thickener tank construction material factor $(F_R) = 1.026(X)^{0.166}$

316-L stainless steel tanks:
Thickener tank construction material factor $(F_S) = 2.045(X)^{0.131}$

Wood-staved tanks:
Thickener tank construction material factor $(F_W) = 0.933(X)^{0.086}$

where X = dry thickener feed, in metric tons per day.

Wood-staved tanks are not ordinarily constructed in diameters larger than 100 feet; therefore, the adjustment factor for wood-staved tanks is valid only for capacities less than or equal to 800 mtpd. (Conversion from gallons per day to metric tons per day is: gallons per day/896.18 = metric tons per day.)

Mechanism Construction Material Factor To determine the capital cost of the thick ener mechanism if the characteristics of the feed slurry require the rakes to be protected, multiply the mechanism cost by the following factor:

Mechanism construction material factor $(F_{C\ RUBBER\text{-}COATED}) = 1.25$
$(F_{C\ STAINLESS\ STEEL}) = 1.50$

Flocculant Factor Flocculants may be added to the thickener to increase the set tling rate of particles in the slurry, with the result that thickener diameter, and corresponding effective settling area required per ton of tailings slurry, may also be reduced. This can, in turn, increase capacity of an existing thickener. If flocculant is added to an existing thickener, add the following costs to the total capital cost:

Flocculant factor $(Y_{F\ SMALL}) = 10{,}737.544(X)^{0.382}$
$(Y_{F\ LARGE}) = 1{,}016.462(X)^{0.712}$
where X = dry thickener feed, in metric tons per day.

This added cost is for preparing the equipment and for adding 3 milligrams per liter of polymer as an emulsion to the thickener, required piping, buildings to house the equipment and store the reagents, and preparation, feed, and storage equipment.

High-Rate Thickener Factor If a High-rate design is chosen over a standard bridge-support design for an operation having the same pulp-handling capacity, multiply the cost obtained from the equipment purchase cost portion of the curve by the following factor:

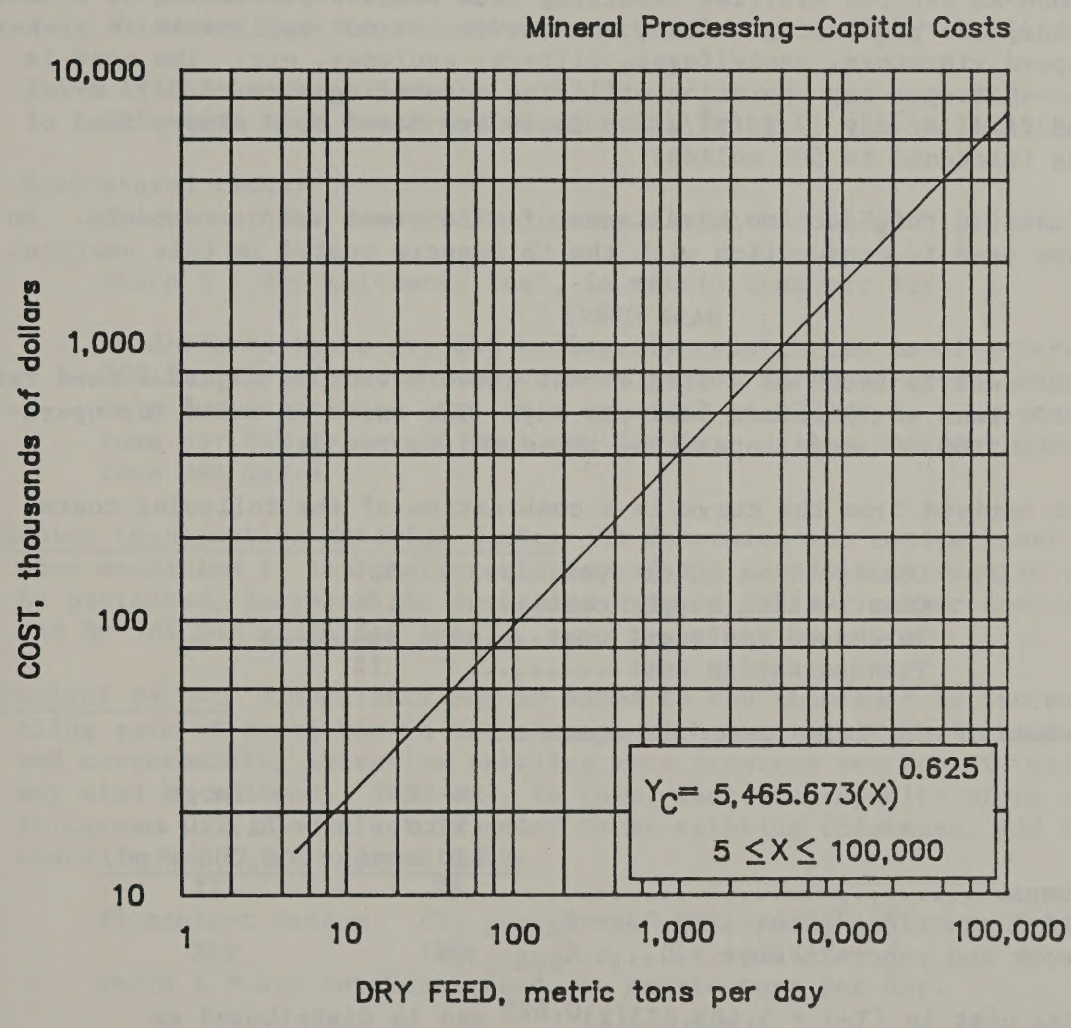
High-rate thickener factor $(F_H) = 0.38$

Additionally, installation cost of the conventional units will be substantially higher than that of the smaller high-capacity units.

Settling Area Adjustment To adjust the capital cost for settling areas differing from the base value of 0.77 m^2/mtpd, multiply (X), metric tons of dry thickener feed per day, by the following factor:

Settling area adjustment $(F_A) = (U/0.77)$
where U = unit area or actual solids loading, in square meters per metric ton per day (see table A-1 in the appendix).

This new value must be used in place of (X) in the base equation when calculating new costs.



6.1.4.1.1. Sedimentation
CONCENTRATE THICKENING

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.4. SOLID-LIQUID SEPARATION

6.1.4.1.2. SEDIMENTATION TAILINGS THICKENING

Included in this section are costs of preliminary tailings dewatering via conventional thickening to reduce the slurry volume prior to transportation to the tailings pond. The cost curves are applicable to dewatering directly from the pond and only with extreme discretion to alternative systems necessary for thickening problem slurries, such as red-mud slurries resulting from bauxite processing or slimes slurries from phosphate processing. Also, the curves are not applicable to shaker screens, high-speed vibrators, centrifuges, filters, cyclones, etc. The cost is based on a three-shift-per-day operation utilizing a settling area of 0.77 m^2/mt of dry thickener feed per day (7.5 ft^2/st). Costs are based on a slurry feed of 25% solids being thickened to 50% solids.

The thickeners used in this section have tanks of mild steel and/or concrete. No hydrocyclones are used in conjunction with the thickeners costed in this section.

BASE CURVE

The total capital cost is based on a single cost curve having an adjusted feed rate (X), in dry metric tons of thickener feed per day. The curve is valid for operations between 5 and 100,000 mtpd, operating three shifts per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	35%
Construction supply cost.....	18%
Purchased equipment cost.....	46%
Transportation cost..........	1%

A typical breakdown of the major cost components is

	Small (5 to 1,120 mtpd)	Large (1,120 to 100,000 mtpd)
Pumps............................	8%	1%
316-L stainless steel tank, earth work and concrete work...........	92%	99%

The total capital cost is $(Y_C) = 5{,}465.673(X)^{0.625}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 1{,}912.986(X)^{0.625}$

(S) Construction Supply Cost $(Y_S) = 983.821(X)^{0.625}$

(E) Purchased Equipment Cost $(Y_E) = 2{,}568.866(X)^{0.625}$

ADJUSTMENT FACTORS

<u>Shift Factor</u> The capital cost equation is based upon a maximum operational effectiveness only possible with a three-shift-per-day operation. Tailings thickeners are not designed to operate on fewer shifts per day on a regularly scheduled basis; therefore, no shift adjustment is made.

<u>Thickener Tank Construction Material Factor</u> A diversity of construction methods and resulting materials of fabrication or concrete are used for thickener tanks. If mild steel is not used, multiply the supplies portion of the total capital cost by one of the following factors:

Mild steel with rubber-lining:
Thickener tank construction material factor $(F_R) = 1.026(X)^{0.166}$

316-L stainless steel tanks:
Thickener tank construction material factor $(F_S) = 2.045(X)^{0.131}$

Wood-staved tanks:
Thickener tank construction material factor $(F_W) = 0.933(X)^{0.086}$

where X = dry thickener feed, in metric tons per day.

Wood-staved tanks are not ordinarily constructed in diameters larger than 100 ft; therefore, the adjustment factor for wood-staved tanks is valid only for capacities less than or equal to 800 mtpd. (Conversion from gallons per day to metric tons per day is: gallons per day/896.18 = metric tons per day.)

<u>Mechanism Construction Material Factor</u> To determine the capital cost of the thickener mechanism if the characteristics of the feed slurry require the rakes to be protected, increase the mechanism cost by 25% for rubber-coated steel rakes and by 50% for stainless steel.

<u>Flocculant Factor</u> Flocculants may be added to the thickener to increase the settling rate of particles in the slurry, with the result that thickener diameter, and corresponding effective settling area required per ton of tailings slurry, may also be reduced. This can, in turn, increase capacity of an existing thickener. If flocculant is added to an existing thickener, add the following costs to the total capital cost:

Flocculant factor $(Y_{F\ SMALL}) = 10{,}737.544(X)^{0.382}$
$(Y_{F\ LARGE}) = 1{,}016.462(X)^{0.712}$
where X = dry thickener feed, in metric tons per day.

This added cost is for preparing the equipment and for adding 3 mg/L of polymer as an emulsion to the thickener, required piping, buildings to house the equipment and store the reagents, and preparation, feed, and storage equipment.

<u>High Rate Thickener Factor</u> If a High rate design is chosen over a standard bridge-support design for an operation having the same pulp-handling capacity, multiply the cost obtained from the equipment purchase cost portion of the curve by the following factor:

High-rate thickener factor $(F_H) = 0.38$

Additionally, installation cost of the conventional units will be substantially higher than that of the smaller high-capacity units.

Settling Area Factor To adjust the capital cost for settling areas differing from the base value of 0.77 m^2/mtpd, multiply (X), metric tons of dry thickener feed per day, by the following factor:

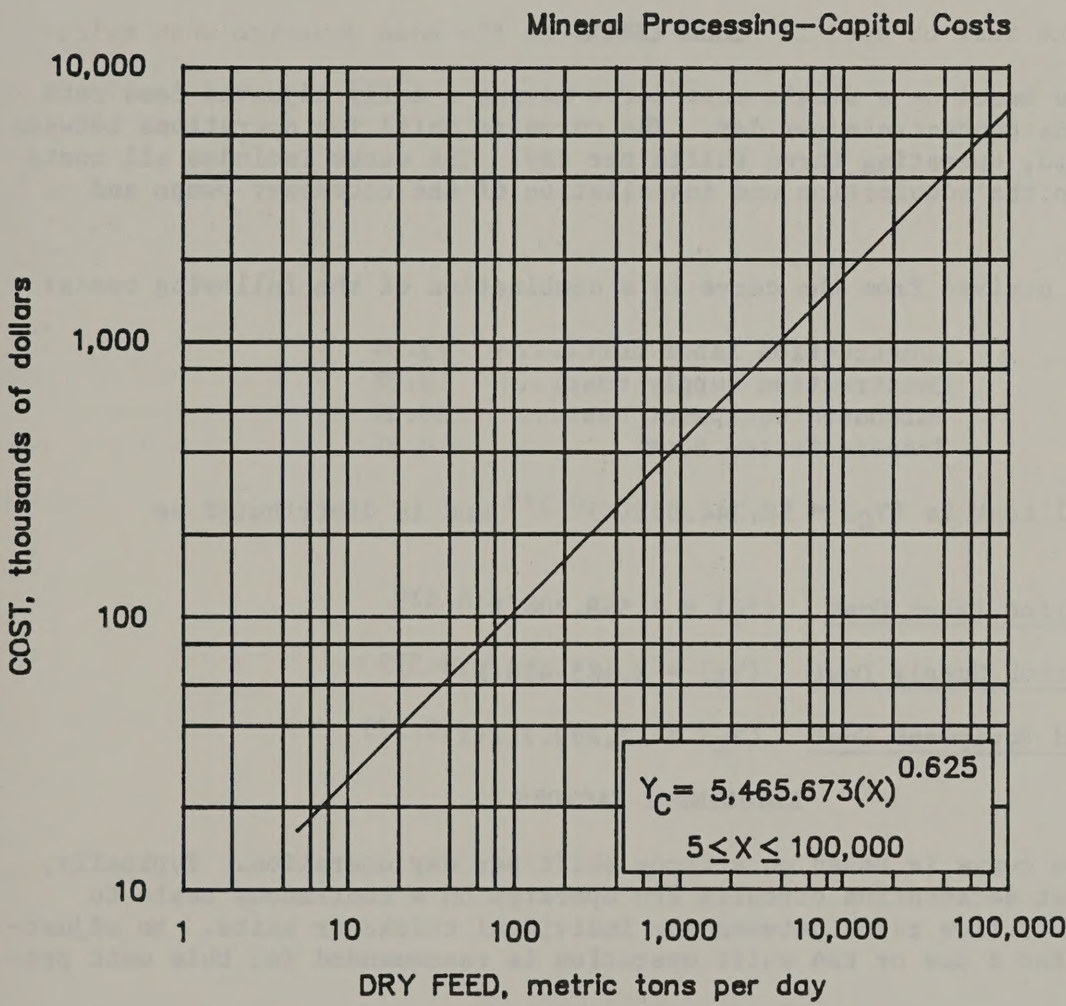
Settling area factor $(F_A) = (U/0.77)$
where U = unit area or actual solids loading, in square meters per metric ton per day

This new value must be used in place of (X) in the base equation when calculating new costs.

See table A-1 for thickener application unit areas.

Amorphous or Colloidal Tailings Factor To adjust the capital cost for amorphous or colloidal tailings that may have an underflow concentration of dry solids of less than 30%, multiply (X), metric tons of dry thickener inflow by the following factor, only if the above settling area factor is not used:

Amorphous or colloidal tailings factor $(F_C) = 2.1$



6.1.4.1.2. Sedimentation
TAILINGS THICKENING

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.4. SOLID-LIQUID SEPARATION

6.1.4.1.3. SEDIMENTATION
COUNTERCURRENT DECANTATION

The capital cost for the countercurrent decantation circuit is based on the utilization of high-capacity thickeners for the acquisition and installation of equipment. The countercurrent decantation circuit includes thickener mechanisms and pumps for four-stage circuit at a settling area of 0.06 m^2/mt of feed per day.

BASE CURVE

The total cost is based on a single cost curve having a daily adjusted feed rate (X) in metric tons concentrate per day. The curve is valid for operations between 175 and 5,500 mtpd, operating three shifts per day. The curve includes all costs as- sociated with the acquisition and installation of the necessary pumps and thick- eners.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	13.9%
Construction supply cost...	19.0%
Purchased equipment cost...	66.3%
Transportation cost........	0.8%

The total capital cost is $(Y_C) = 18,344.853(X)^{0.579}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 2,568.208(X)^{0.579}$

(S) Construction Supply Cost $(Y_S) = 3,485.426(X)^{0.579}$

(E) Purchased Equipment Cost $(Y_E) = 12,290.711(X)^{0.579}$

ADJUSTMENT FACTORS

Shift Factor The curve is based on a three shift per day operation. Typically, countercurrent decantation circuits are operated on a continuous basis to maintain steady flow rates between the individual thickener units. No adjustment factor for a one or two shift operation is recommended for this unit process.

Number of Thickener Units Factor The base curve consists of four-unit counter current decantation circuit. To adjust the base curve for other than four thickener units, multiply the cost obtained from the curve by the following factor:

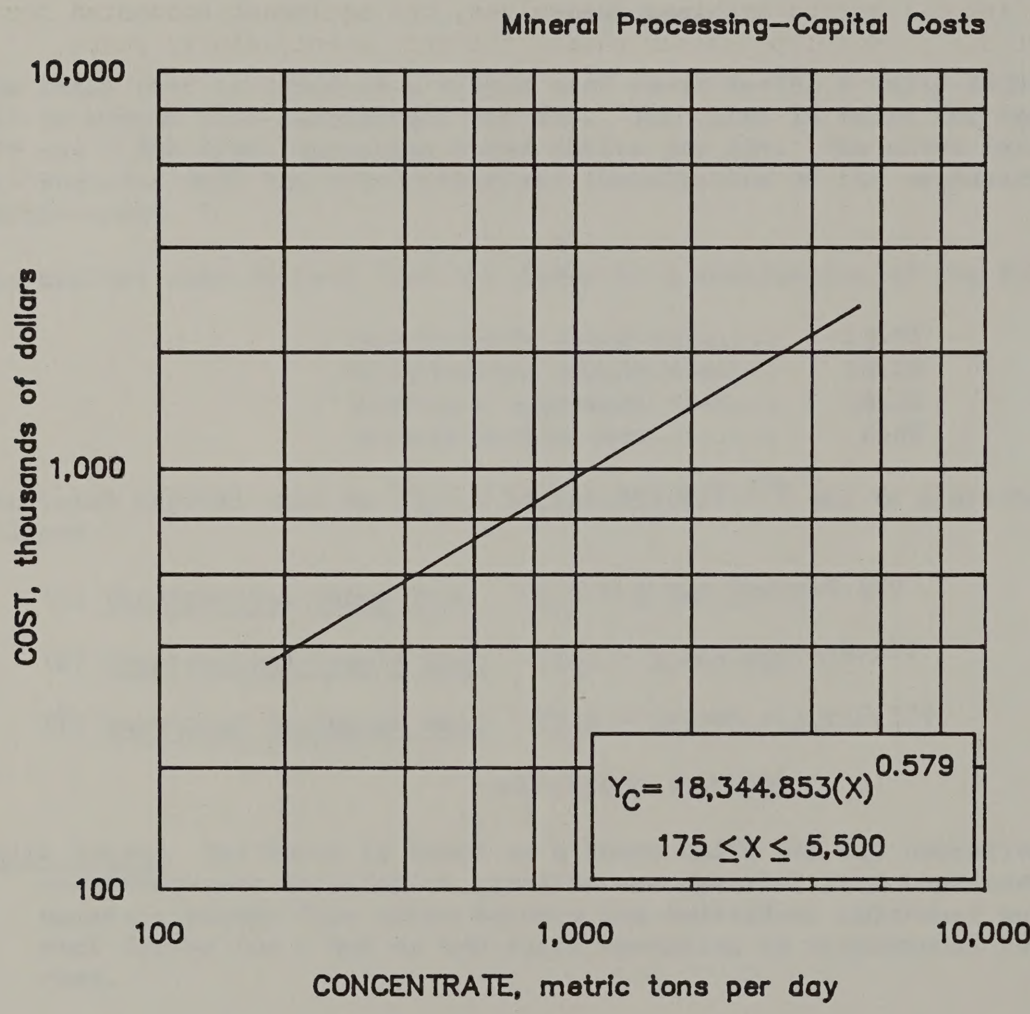
Number of thickener units factor $(F_U) = 0.234(U)+0.064$
where U = total number of thickener units.

Settling Area Factor The base curve is based on a settling area of 0.06 m^2/mt of feed per day. To adjust the base curve for different settling areas, add the following factor to the total capital cost:

Settling area factor $(F_A) = 98{,}000{,}000(A)-5{,}880{,}000$
where A = actual settling, in square meters per metric ton of feed per day.

Conventional Thickener Factor The curve is based on the utilization of high capacity thickeners. To adjust the base curve for conventional thickeners, multiply the cost obtained from the curve by the following factor:

Conventional thickener factor $(F_C) = 1.59$



6.1.4.1.3. Sedimentation
COUNTER—CURRENT DECANTATION

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.4. SOLID-LIQUID SEPARATION

6.1.4.2.1. CONCENTRATE FILTRATION VACUUM, DISK, AND DRUM FILTRATION

The capital cost for concentrate filtration only covers the acquisition and installation of continuous-vacuum filtration equipment. In particular, the cost applies to rotary-disk filter equipment; however, for drum-type or horizontal filter equipment, the cost still represents an approximation.

In addition to the disk-filtration machines themselves, the equipment accounted for in this section consists of wet-type vacuum pumps, filtrate pumps, slurry pumps, air blowers, belt conveyors, and all associated piping and filtrate-receiving facilities. If wet-type vacuum pumps are not employed by the user, then the additional cost of any necessary moisture traps, barometric legs, and associated piping should be added to the filtration base curve cost. Furthermore, if auxiliary steam drying is to be utilized, the extra cost of the required steam hoods and associated equipment should also be added to the curve's base cost.

BASE CURVE

The total cost is based on a single cost curve having a output rate (X), in metric tons concentrate per day. The curve is valid for operations between 5 and 60,000 mtpd, operating three shifts per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	12%
Construction supply cost...	18%
Purchased equipment cost...	67%
Transportation cost........	3%

The capital cost consists of the following typical range of major equipment costs:

	Small (5 to 30,000 mtpd)	Large (30,000 to 60,000 mtpd)
Disk-filtration machines....	60%	56%
Vacuum pumps................	12%	33%
Filtrate pumps..............	2%	2%
Slurry pumps................	3%	3%
Air blowers.................	2%	2%
Belt conveyors..............	21%	4%

The total capital cost is $(Y_C) = 5,716.967(X)^{0.650}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 743.206(X)^{0.650}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 1,086.224(X)^{0.650}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 3,887.538(X)^{0.650}$

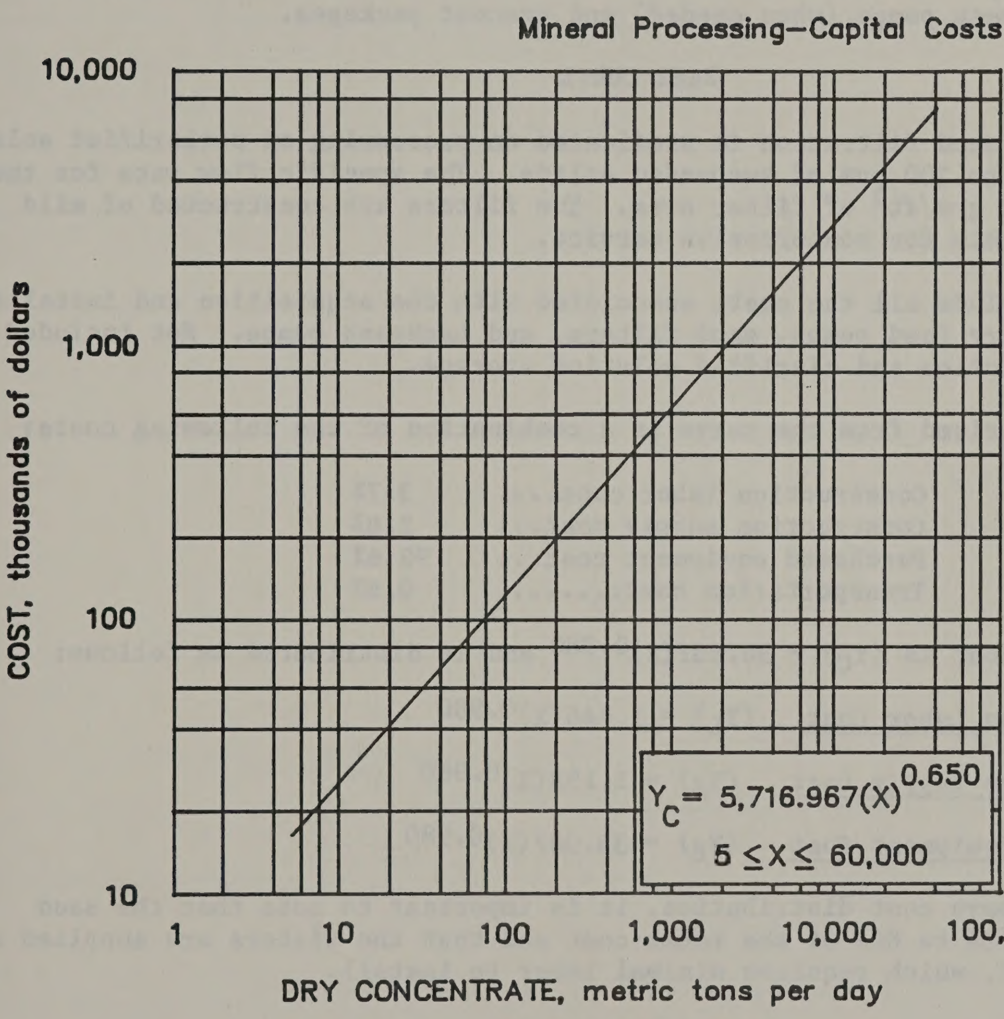
ADJUSTMENT FACTORS

Filtration Rate Factor The capital cost curve is predicated on a filtration rate of 490 kg/m^2/h (approximately 100 lb/ft^2/h). To allow for a different filtration rate, multiply the cost obtained from the curve by the following factor:

Filtration rate factor $(F_R) = (R)^{0.650}/56.057$
where R = actual filtration rate.

Pressure Filter Factor To adjust the capital cost for the substituted use of automatic pressure filters (e.g., Larox or Lasta-type filter presses), multiply the cost obtained from the curve by the following factor:

Pressure filter factor $(F_P) = 1.71$



6.1.4.2.1. Concentrate filtration
VACUUM, DISK, AND DRUM FILTRATION

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.4. SOLID-LIQUID SEPARATION

6.1.4.2.2. CONCENTRATE FILTRATION PRESSURE FILTRATION--SAND

The capital cost for pressure filtration is for the acquisition and installation of the equipment needed to produce a clarified solution. The total cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of solution per day. The curves are valid for operations between 1,900 and 31,900 mtpd, operating three shifts per day. The pressure filtration circuit includes feed pumps, pressure filters, backwash pumps (when needed) and precoat packages.

BASE CURVE

The base curve for sand filtration is predicated on processing an unclarified solution containing up to 200 ppm of suspended solids. The specific flow rate for the sand filters was 12 gpm/ft^2 of filter area. The filters are constructed of mild steel and are suitable for noncorrosive service.

The cost curves include all the costs associated with the acquisition and installation of the necessary feed pumps, sand filters, and backwash pumps. Not included are unclarified solution and clarified solution storage.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	3.7%
Construction supply cost...	2.8%
Purchased equipment cost...	92.6%
Transportation cost........	0.9%

The total capital cost is $(Y_C) = 38.651(X)^{0.980}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 1.546(X)^{0.980}$

(S) Construction Supply Cost $(Y_S) = 1.198(X)^{0.980}$

(E) Purchased Equipment Cost $(Y_E) = 35.907(X)^{0.980}$

In examining the above cost distribution, it is important to note that the sand filters represent 70% to 80% of the total cost and that the filters are supplied as a skid mounted unit, which requires minimal labor to install.

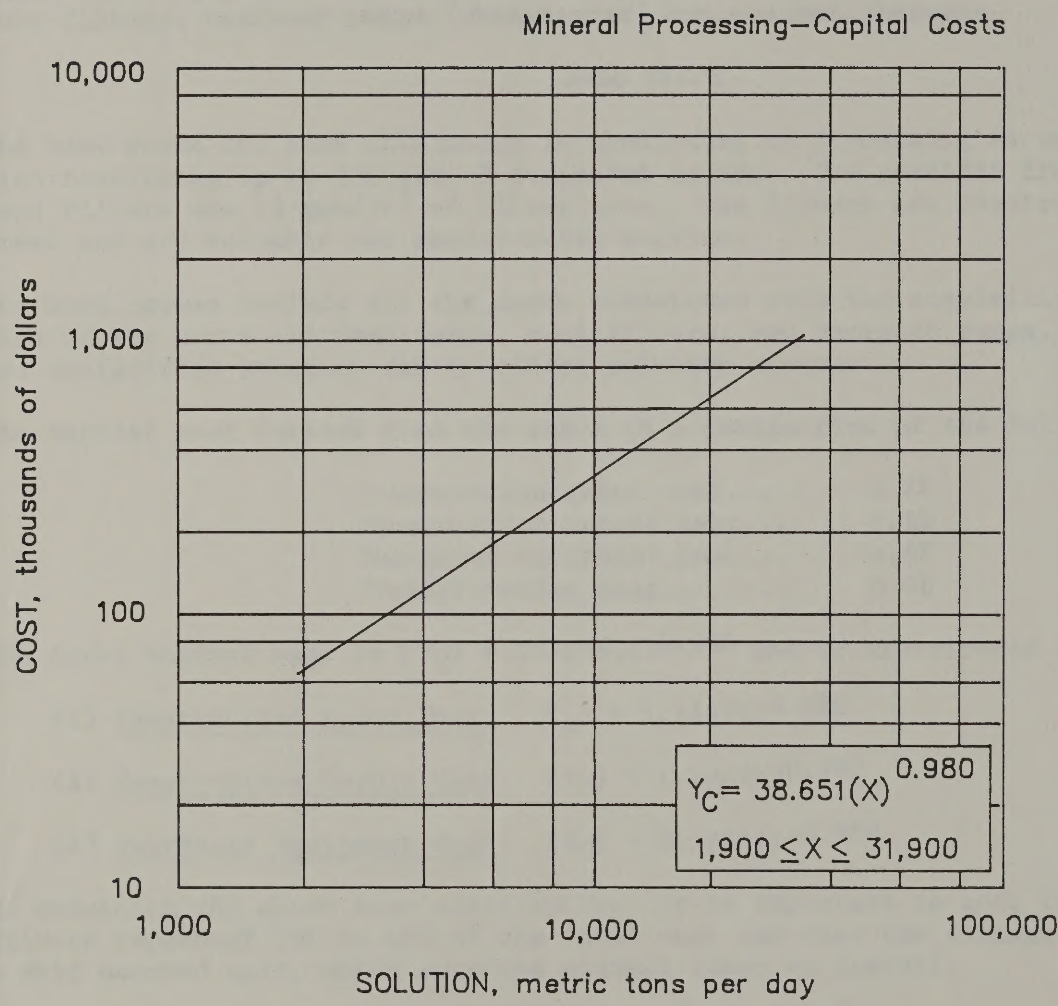
ADJUSTMENT FACTORS

Sand Filter Factor There are two adjustment factors for the sand filter: (1) specific flowrate and (2) construction material for corrosive resistance. The capital cost for the base curve is based on a flowrate of 12 gpm per square foot of filter area. To adjust the base curve for other flowrates, multiply the cost obtained from the curve by the following factor:

Sand filter factor $(F_F) = (12/S)$
where S = new specific flow rate, in gallons per minute per square foot of filter media.

Acid Circuit Factor The use of sand filters in an acid circuit (sulfuric or hydro chloric) will raise the capital cost. To adjust for an acid circuit, multiply the cost obtained from the curve by the following factor:

Acid circuit factor $(F_A) = 1.12$



6.1.4.2.2. Concentrate filtration
PRESSURE FILTRATION—SAND

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.4. SOLID-LIQUID SEPARATION

6.1.4.2.3. CONCENTRATE FILTRATION PRESSURE FILTRATION--PRECOAT

The capital cost for pressure filtration is for the acquisition and installation of the equipment needed to produce a clarified solution. The total cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of solution per day. The curves are valid for operations between 2,100 and 16,100 mtpd, operating three shifts per day. The pressure filtration circuit includes feed pumps, pressure filters, backwash pumps (when needed), and precoat packages.

BASE CURVE

The base curve for precoat filtration is predicated on utilizing vertical leaf pressure precoat filters. The solution to be processed can contain up to 200 ppm of suspended solids. The specific flow rate for the precoat filter was 0.6 gpm/ft^2 of filter area. The filters are constructed of mild steel.

The cost curves include all the costs associated with the acquisition and installation of the necessary feed pumps, precoat tanks and agitation, body feed tanks and agitation, sludge disposal tanks, and pump and precoat filters.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	4.4%
Construction supply cost...	2.3%
Purchased equipment cost...	92.6%
Transportation cost........	0.7%

The total capital cost is $(Y_C) = 1,171.876(X)^{0.658}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 51.563(X)^{0.658}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 35.156(X)^{0.658}$

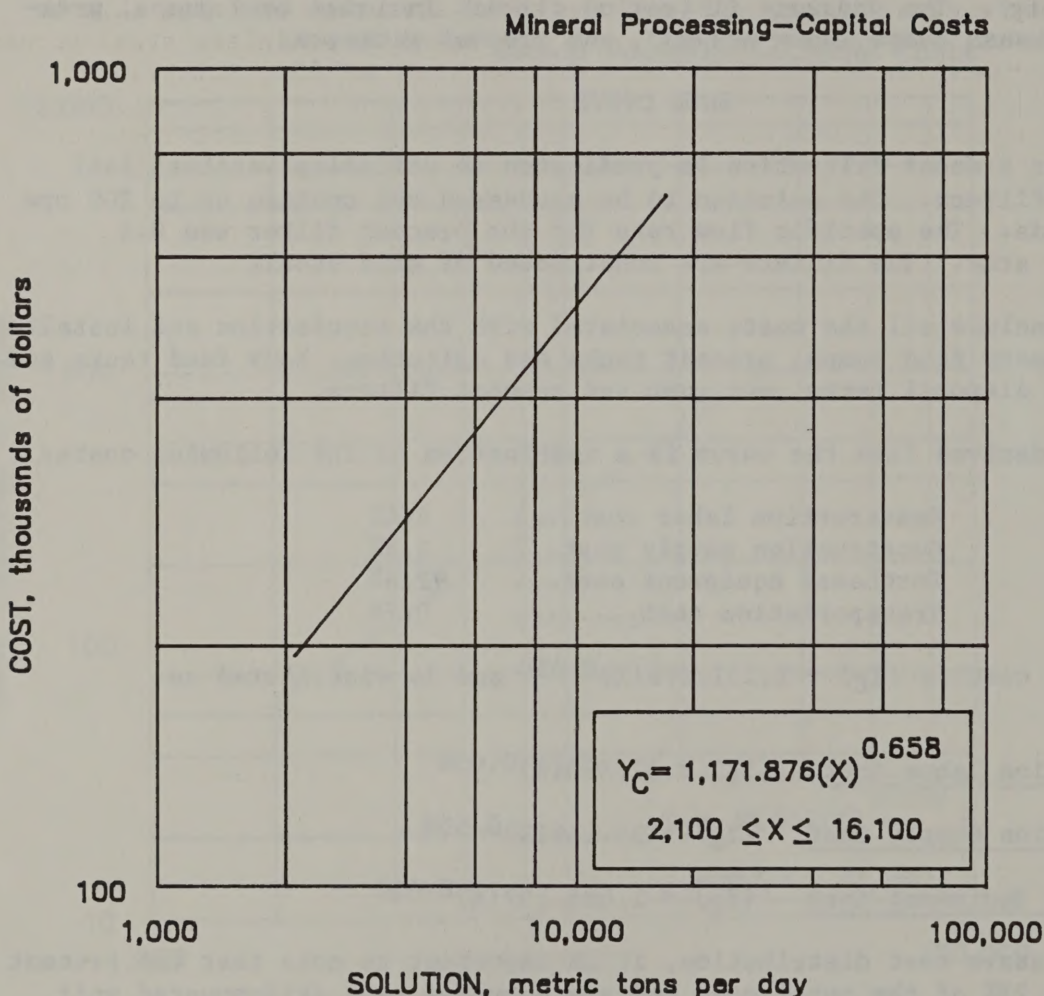
(E) <u>Purchased Equipment Cost</u> $(Y_E) = 1,085.157(X)^{0.658}$

In examining the above cost distribution, it is important to note that the precoat filters represent 75% of the total cost and are supplied as a skid-mounted unit which requires minimal installation cost.

ADJUSTMENT FACTOR

<u>Precoat Filter Factor</u> The capital cost for the base curve is based on a flow rate of 0.6 gpm per square foot of filter media. To adjust for flow rates other than 0.6 gpm, multiply the cost obtained from the curve by the following factor:

Precoat filter factor $(F_P) = (0.6/S)$
where S = new specific flowrate, in gallons per minute per square foot of filter media.



6.1.4.2.3. Concentrate filtration
PRESSURE FILTRATION—PRECOAT

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.4. SOLID-LIQUID SEPARATION

6.1.4.2.4. CONCENTRATE FILTRATION
CENTRIFUGAL FILTRATION

The capital cost of centrifugal filtration is calculated from estimated daily solid feed, and based on screen-bowl-type centrifuges. Screen bowl centrifuges are normally used for feeds without an excess of minus 325 mesh fines. They are considered high-output units noted for their ability to produce a drier product than an equivalent capacity vacuum filter, and have the added advantage of being able to wash the filter cake. The costs for this curve are based on stainless steel screen bowl units with ceramic facing on high wear areas such as scrolls, inlets, and screens. If liquid clarification, desliming, or slurry dewatering are required, solid bowl centrifuges are usually specified. See the adjustment factor section for such uses.

The total cost is based on a single cost curve having a production rate (X), in metric tons of solids handled per day. The curve is valid for operations between 5 and 30,000 mtpd, operating three shifts per day.

BASE CURVE

Total capital cost accounts for purchase and installation of necessary centrifuges and motors to handle the expected feed. Charges for shipping, handling, setting, aligning, foundation preparation, frame construction, instrumentation, wiring, piping, site clean up, and sales tax are all included.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	15%
Construction supply cost.....	22%
Purchased equipment cost.....	63%

The total capital cost is $(Y_C) = 2,339.982(X)^{0.835}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 350.997(X)^{0.835}$

(S) Construction Supply Cost $(Y_S) = 514.796(X)^{0.835}$

(E) Purchased Equipment Cost $(Y_E) = 1,474.189(X)^{0.835}$

ADJUSTMENT FACTORS

Solid Bowl Centrifuge Factor In situations where water clarification is required, or excessive fines must be dewatered, a solid bowl centrifuge is often called for. If solid bowl centrifuges are used, multiply the equipment portion of the capital cost by the following factor to account for the difference in equipment prices:

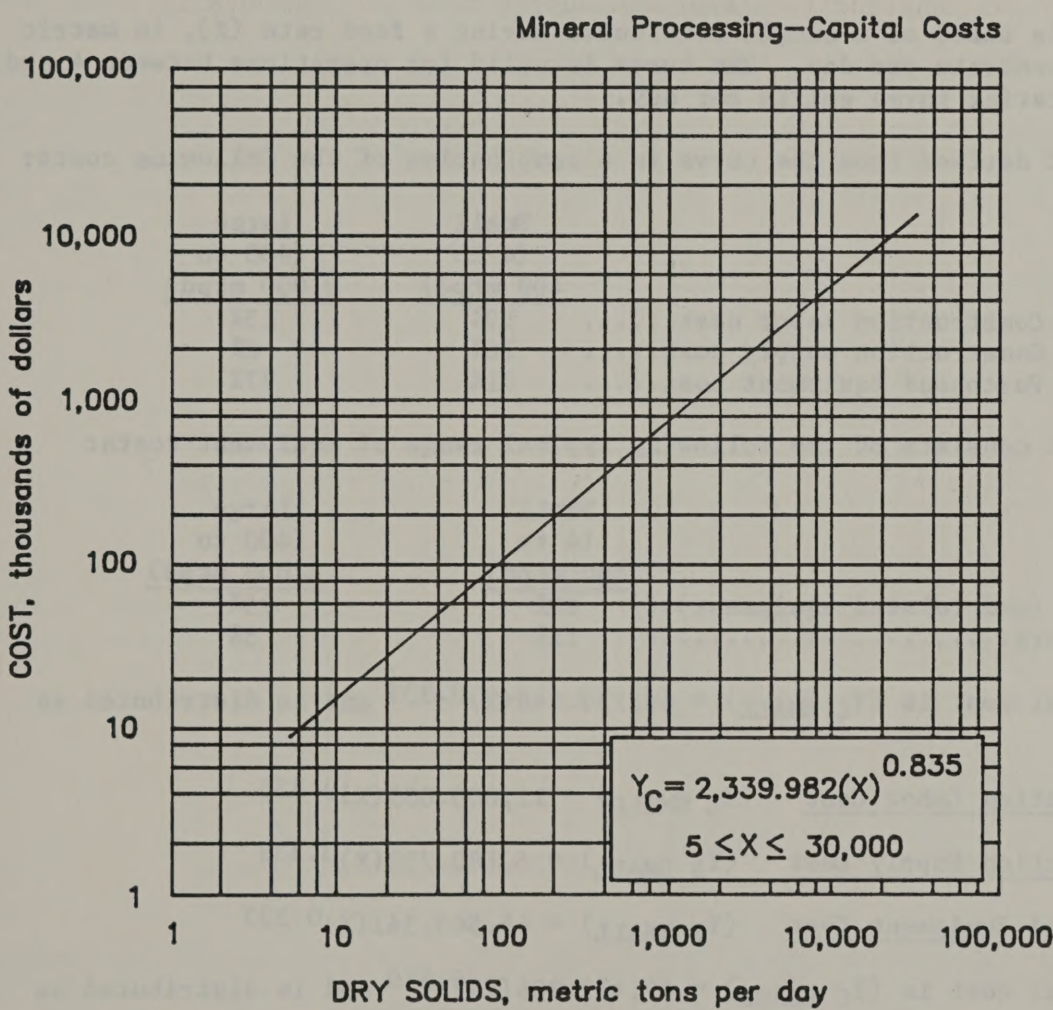
Purchased equipment factor $(F_E) = 0.873$

Installation and construction labor and supply costs will generally remain constant.

Abrasive or Corrosive Feeds Factor If abrasive or corrosive feeds are anticipated, centrifuges are often constructed from materials other than stainless steel. These materials and their costs vary greatly. However, based on a machine constructed of nickel alloy (Monel), multiply the purchased equipment portion of the capital cost by the following factor to account for increased material cost:

Purchased equipment factor $(F_E) = 0.549(X)^{0.133}$
where X = solids handled, in metric tons per day.

Installation and construction labor and supply costs will generally remain constant.



6.1.4.2.4. Concentrate filtration
CENTRIFUGAL FILTRATION

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.4. SOLID-LIQUID SEPARATION

6.1.4.3. CONCENTRATE DRYING

Drying capital costs are for the acquisition and installation of equipment for drying concentrate on a 24-h/d basis. Major items of equipment are rotary-drum dryers, cyclone dust collectors, wet scrubbers, vapor fans, and conveyors.

BASE CURVE

The total cost is based on a single cost curve having a feed rate (X), in metric tons of dry concentrate per day. The curve is valid for operations between 4 and 8,000 mtpd, operating three shifts per day.

The capital cost derived from the curve is a combination of the following costs:

	Small (4 to 400 mtpd)	Large (400 to 8,000 mtpd)
Construction labor cost......	19%	15%
Construction supply cost.....	10%	8%
Purchased equipment cost.....	71%	77%

The capital cost consists of the following typical range of equipment costs:

	Small (4 to 400 mtpd)	Large (400 to 8,000 mtpd)
Dryers (and related equipment)..	88%	95%
Conveyors......................	12%	5%

The total capital cost is $(Y_{C\ SMALL}) = 64{,}759.148(X)^{0.333}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ SMALL}) = 11{,}009.055(X)^{0.333}$

(S) Construction Supply Cost $(Y_{S\ SMALL}) = 5{,}180.732(X)^{0.333}$

(E) Purchased Equipment Cost $(Y_{E\ SMALL}) = 48{,}569.361(X)^{0.333}$

The total capital cost is $(Y_{C\ LARGE}) = 47{,}412.206(X)^{0.370}$ and is distributed as follows:

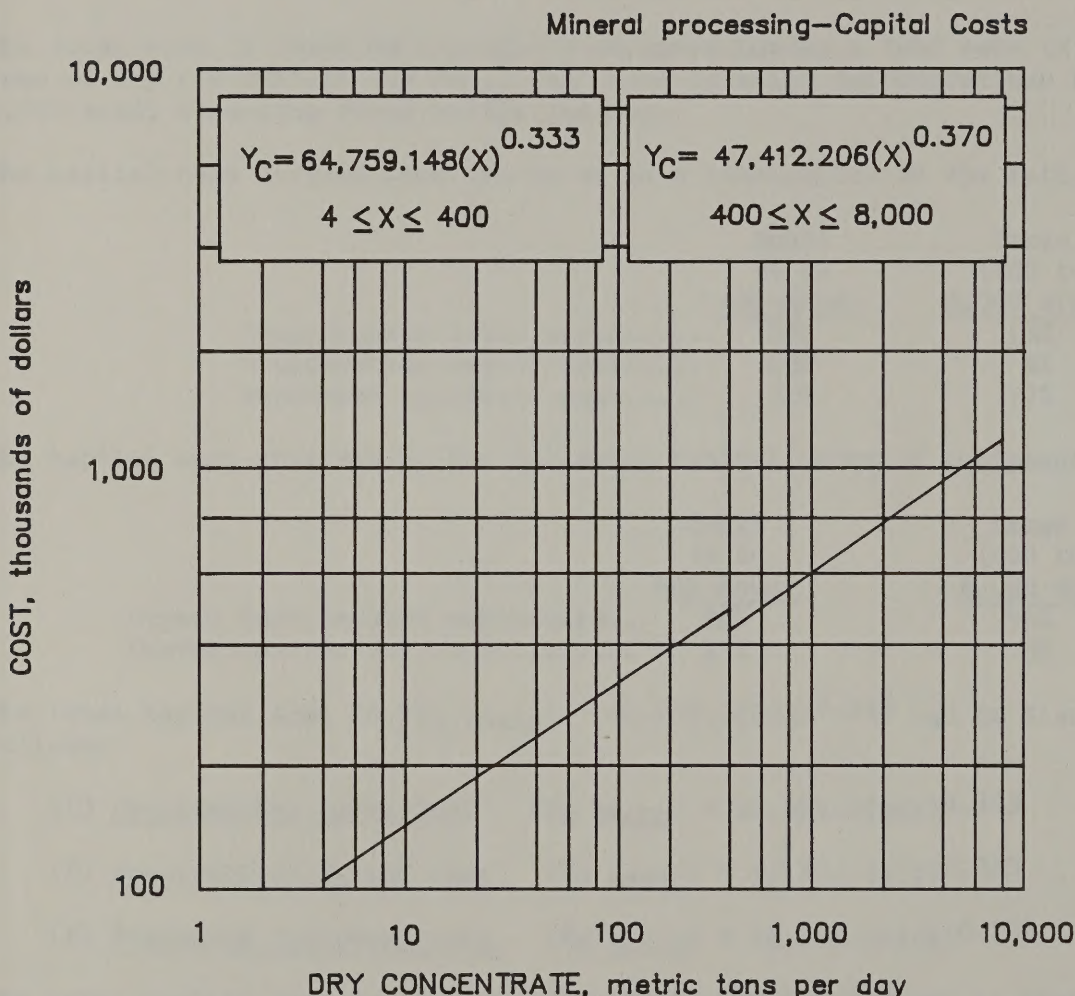
(L) Construction Labor Cost $(Y_{L\ LARGE}) = 8{,}060.075(X)^{0.370}$

(S) Construction Supply Cost $(Y_{S\ LARGE}) = 3{,}792.977(X)^{0.370}$

(E) Purchased Equipment Cost $(Y_{E\ LARGE}) = 35{,}559.154(X)^{0.370}$

ADJUSTMENT FACTOR

Shift Factor The curve is based on a three-shift-per-day operation. Because it would be impractical to operate a dryer less than 24 hpd (because of the large heat losses connected with starting up and shutting down), no shift adjustment factors should be used.



6.1.4.3. Concentrate drying

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.4. SOLID-LIQUID SEPARATION

6.1.4.4. TRANSPORT AND PLACE TAILINGS

The cost curve is for acquisition and installation of the equipment and materials required to transport tailings in a slurry composed of 50% solids to a disposal pond. Major items included in the curve are pumps, cyclones, and steel pipe. The pipe has been sized so that the average total head is 30 m, including a static head of 15 m. The pipeline length for the base curve is 1 km.

BASE CURVE

The total cost is based on a single cost curve having a disposal rate (X), in metric tons tailings per day (dry weight equivalent). The curve is valid for operations between 100 and 100,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition and installation of pumps, motors, pipeline, and cyclones.

The capital cost derived from the curve is a combination of the following costs:

	Small (100 to 10,000 mtpd)	Large (10,000 to 100,000 mtpd)
Installation labor cost........	21%	18%
Installation materials cost....	51%	28%
Purchased equipment cost.......	28%	54%

The installation labor cost consists of 91% labor and 9% equipment operation. The equipment operation component of the installation labor cost consists of 50% fuel and lubrication, 48% repair parts, and 2% tires.

The capital cost consists of the following typical range of equipment costs:

	Small (100 to 10,000 mtpd)	Large (10,000 to 100,000 mtpd)
Pumps....................	70%	40%
Cyclones................	30%	60%

The total capital cost is $(Y_C) = 599.252(X)^{0.630}$ and is distributed as follows:

(L) <u>Installation Labor Cost</u> $(Y_{L\ SMALL}) = 125.842(X)^{0.630}$
(S) <u>Installation Materials Cost</u> $(Y_{S\ SMALL}) = 305.619(X)^{0.630}$
(E) <u>Purchased Equipment Cost</u> $(Y_{E\ SMALL}) = 167.791(X)^{0.630}$

(L) <u>Installation Labor Cost</u> $(Y_{L\ LARGE}) = 107.865(X)^{0.630}$
(S) <u>Installation Materials Cost</u> $(Y_{S\ LARGE}) = 167.791(X)^{0.630}$
(E) <u>Purchased Equipment Cost</u> $(Y_{E\ LARGE}) = 323.596(X)^{0.630}$

ADJUSTMENT FACTORS

Gravity Flow Factor If tailings flow by gravity to a ponding area, multiply the cost obtained from the curve by the following factor:

Gravity flow factor $(F_{G\ SMALL}) = 0.3$
$(F_{G\ LARGE}) = 0.5$

Pipeline Length Factor The pipeline is an extra-strength steel pipe 1 km long. For other lengths, multiply the cost obtained from the curve by the following factor:

Pipeline length factor $(F_{L\ SMALL}) = L$
$(F_{L\ LARGE}) = 0.6(L)$
where L = length, in kilometers.

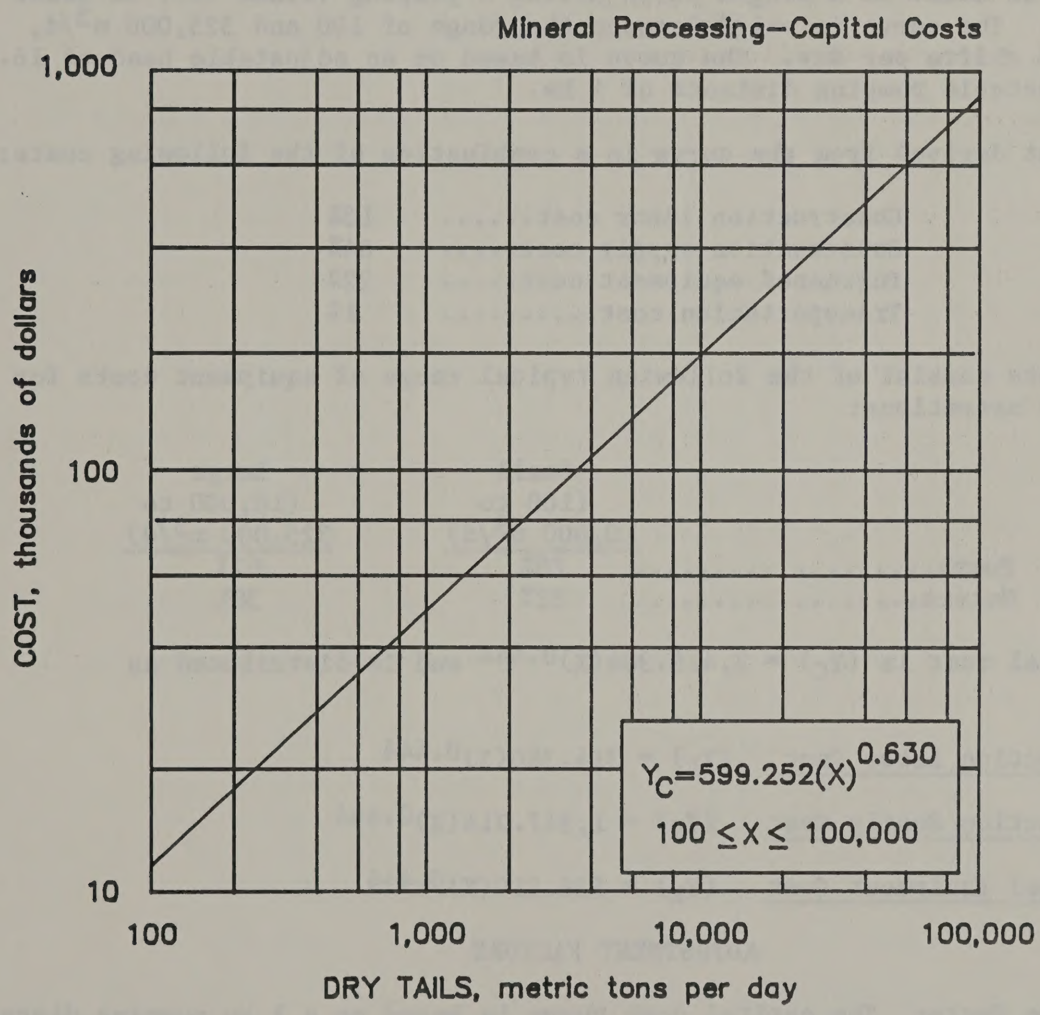
Pipeline Type Factor Where concrete pipe is used instead of steel pipe, multiply the construction supplies cost by the following factor:

Construction supplies factor $(F_S) = 0.6$

Use of cyclones The curve is based on cyclone use that allows distribution of tailings at a rate of 40 mt (dry weight equivalent) per cyclone per hour, 24 h/d, with a 50% utilization of cyclones. The cyclones are placed on the berm of the tailings dam at 9-m intervals. The number of cyclones installed is dependent principally on the length of the dam and spacing between the cyclones. If the number of cyclones are known, the costs should be multiplied by the following factor:

Cyclone factor $(F_C) = 288(N)/(X)$
where N = desired number of cyclones
and X = tailings, in metric tons per day.

If dry tailings are being transported, use a front-end loader and trucks for loading and transporting the tailings (see section 2.2.2.6.).



6.1.4.4. Transport and place tailings

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.4. SOLID-LIQUID SEPARATION

6.1.4.5. WATER RECLAMATION

The cost curve covers acquisition and installation of equipment and materials required to return decanted tailings pond water to the mill.

BASE CURVE

The total cost is based on a single curve having a pumping volume (X), in cubic meters per day. The curve is valid between the range of 100 and 325,000 m^3/d, operating three shifts per day. The curve is based on an adjustable head of 16.5 m, and for an adjustable pumping distance of 1 km.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	13%
Construction supply cost.....	64%
Purchased equipment cost.....	22%
Transportation cost..........	1%

The capital costs consist of the following typical range of equipment costs for small and large operations:

	Small (100 to 10,000 m^3/d)	Large (10,000 to 325,000 m^3/d)
Pumps....................	78%	62%
Motors...................	22%	38%

The total capital cost is $(Y_C) = 2{,}418.304(X)^{0.444}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 314.380(X)^{0.444}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 1{,}547.714(X)^{0.444}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 556.210(X)^{0.444}$

ADJUSTMENT FACTORS

<u>Pumping Distance Factor</u> The capital cost curve is based on a 1 km pumping distance. For actual distances, multiply the cost obtained from the curve by the following factor:

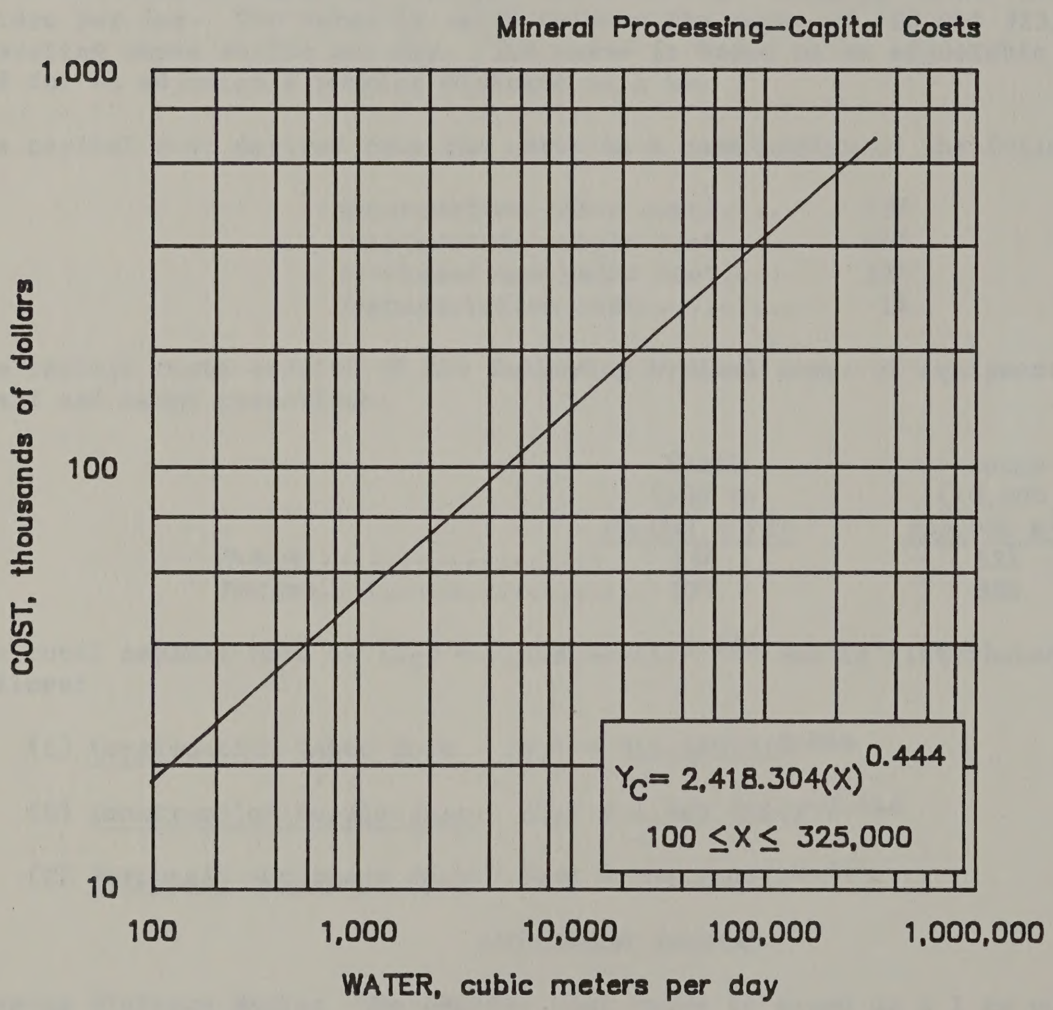
Pumping distance factor $(F_D) = 0.320+0.680(D)$
where D = actual pumping distance, in kilometers.

<u>Pumping Head Factor</u> The capital cost curve is based on a 15-meter static head (lift) and 1.5-meter friction head. This friction head applies to a 1 km

standard steel pipeline. For actual heads, multiply the cost obtained from the curve by the following factor:

Pumping head factor $(F_H) = 0.740+0.0158(H)$
where H = actual head (static, friction, velocity, and fitting), in meters.

For preliminary estimates of (H), add to the actual static head (lift) 1 to 2 m for each kilometer of pipeline through which water is pumped. For accurate determinations of (H), add to the actual static head the sum of friction, velocity, and fitting heads obtained from hydraulics handbooks for actual pipe quality, pipe diameter, and pipeline pumping distance.



6.1.4.5. Water reclamation

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.1.1. ACID LEACHING BERYLLIUM ORE

The capital cost includes the acquisition and installation of equipment items associated with the acid leaching circuit. The capital cost is based on a single curve having an adjusted feed rate (X), in metric tons of ore or concentrate leached per day. The curve is valid for operations between 85 and 560 mtpd, operating three shifts per day.

BASE CURVE

The total capital cost for beryllium ore is for the acquisition and installation of the purchased equipment items.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	39.5%
Construction supply cost...	19.3%
Purchased equipment cost...	40.9%
Transportation cost........	0.3%

The total capital cost is $(Y_C) = 44,887.857(X)^{0.367}$ and is distributed as follows:

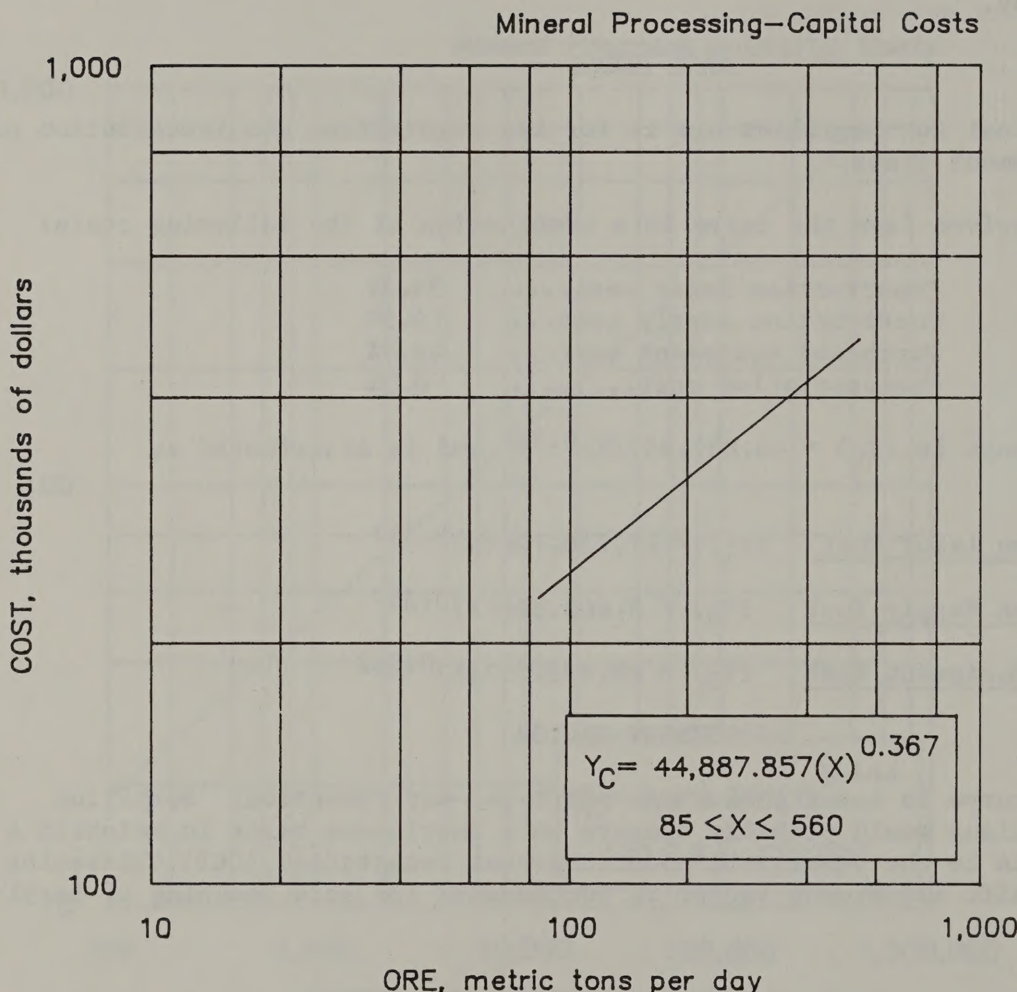
(L) <u>Construction Labor Cost</u> $(Y_L) = 17,730.704(X)^{0.367}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 8,663.356(X)^{0.367}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 18,493.797(X)^{0.367}$

ADJUSTMENT FACTOR

<u>Shift Factor</u> The curve is based on a three-shift-per-day operation. Beryllium leaching operations would probably operate on a continuous basis to maintain a steady flow rate to the subsequent countercurrent decantation (CCD) thickening circuit. No shift adjustment factor is recommended for acid leaching of beryllium ores.



6.1.5.1.1. Acid leaching
BERYLLIUM ORE

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.1.2. ACID LEACHING CARBONATE

The capital cost includes the acquisition and installation of equipment items associated with the acid leaching circuit. The capital cost curve is based on a single cost curve having an adjusted feed rate (X), in metric tons of ore or concentrate leached per day. The curve is valid for operations between 4 and 1,700 mtpd, operating three shifts per day.

BASE CURVE

The total capital cost is based on a single curve at an adjusted feed rate (X) for the acquisition and installation of the purchased equipment items. For the base case, it has been assumed that the concentrate contains 5% carbonates as CO_3, and is leached for 4 h.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	42.4%
Construction supply cost...	16.3%
Purchased equipment cost...	41.0%
Transportation cost........	0.3%

The total capital cost is $(Y_C) = 7{,}337.140(X)^{0.541}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 3{,}110.947(X)^{0.541}$

(S) Construction Supply Cost $(Y_S) = 1{,}195.954(X)^{0.541}$

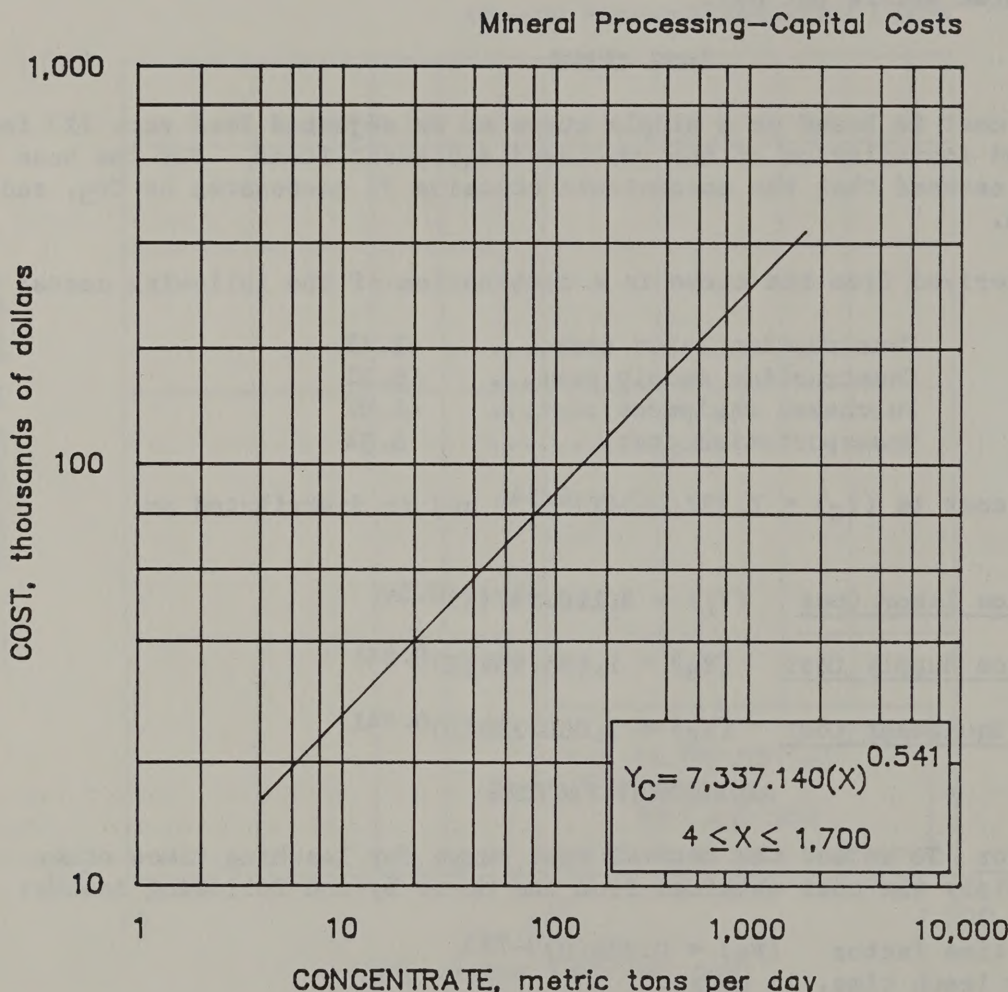
(E) Purchased Equipment Cost $(Y_E) = 3{,}030.239(X)^{0.541}$

ADJUSTMENT FACTORS

Leaching Time Factor To adjust the capital cost curve for leaching times other than 4 h, multiply the cost obtained from the curve by the following factor:

Leaching time factor $(F_H) = 0.339(H)^{0.775}$
where H = leach time, in hours.

Percent Carbonate Factor There is no adjustment factor for concentrates that con tain other than 5% carbonates.



6.1.5.1.2. Acid leaching
CARBONATE

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.1.3. ACID LEACHING COPPER ORE

The capital cost includes the acquisition and installation of equipment items associated with the acid leaching circuit. The capital cost is based on a single curve having an adjusted feed rate (X), in metric tons of ore or concentrate leached per day. The curve is valid for operations between 3,000 and 10,500 mtpd, operating three shifts per day.

BASE CURVE

The total capital cost for copper ore is for the acquisition and installation of the purchased equipment items.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	20.6%
Construction supply cost...	54.7%
Purchased equipment cost...	24.3%
Transportation cost........	0.4%

The total capital cost is $(Y_C) = 1{,}665.555(X)^{0.792}$ and is distributed as follows:

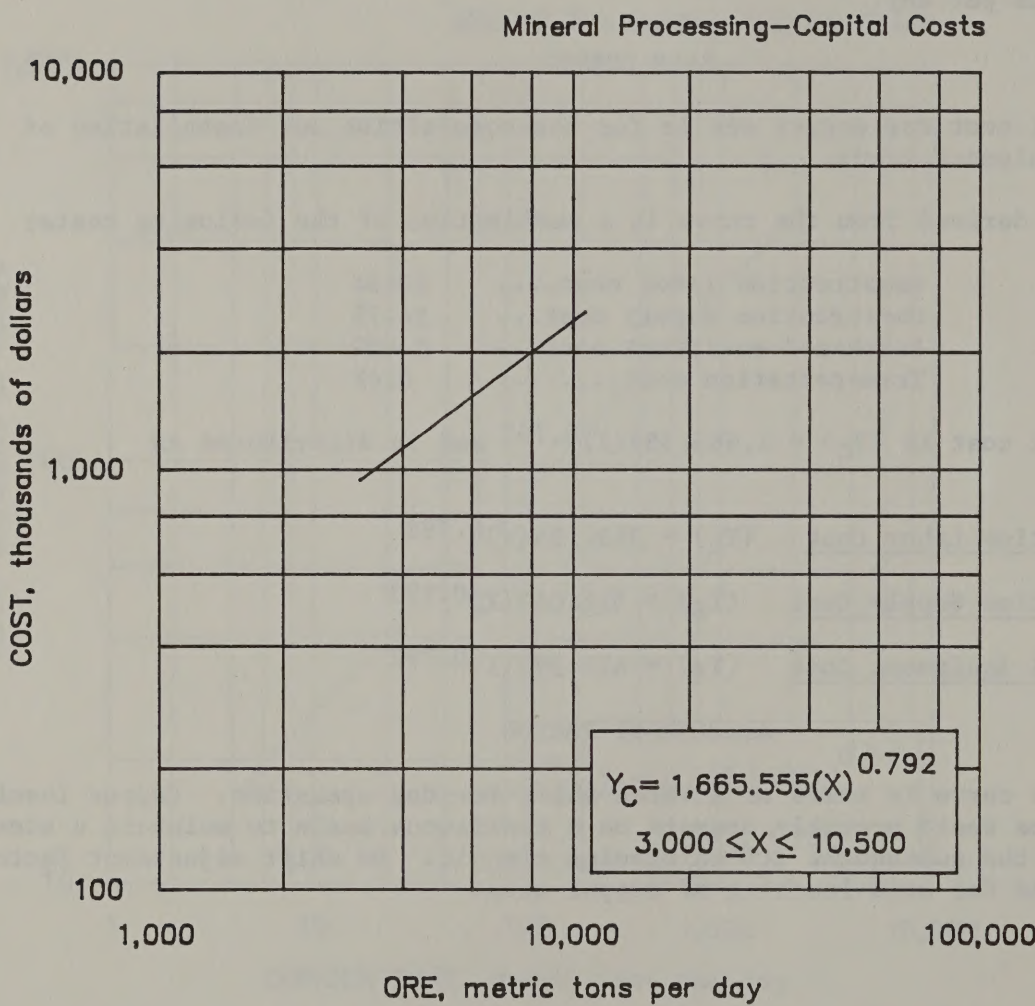
(L) Construction Labor Cost $(Y_L) = 343.104(X)^{0.792}$

(S) Construction Supply Cost $(Y_S) = 911.059(X)^{0.792}$

(E) Purchased Equipment Cost $(Y_E) = 411.392(X)^{0.792}$

ADJUSTMENT FACTOR

Shift Factor The curve is based on a three-shift-per-day operation. Copper leaching operations would probably operate on a continuous basis to maintain a steady flow rate to the subsequent CCD thickening circuit. No shift adjustment factor is recommended for acid leaching of copper ores.



6.1.5.1.3. Acid leaching
COPPER ORE

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.1.4. ACID LEACHING PYROCHLORE

The capital cost includes the acquisition and installation of equipment items associated with the acid leaching circuit. The capital cost is based on a single curve having an adjusted feed rate (X), in metric tons of ore or concentrate leached per day. The curve is valid for operations between 4 and 170 mtpd, operating three shifts per day.

BASE CURVE

The total capital cost for pyrochlore concentrate is for the acquisition and installation of the purchased equipment items for a two-stage leach circuit.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	24.8%
Construction supply cost...	8.3%
Purchased equipment cost...	66.5%
Transportation cost........	0.4%

The total capital cost is $(Y_C) = 49{,}424.843(X)^{0.342}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 12{,}257.361(X)^{0.342}$

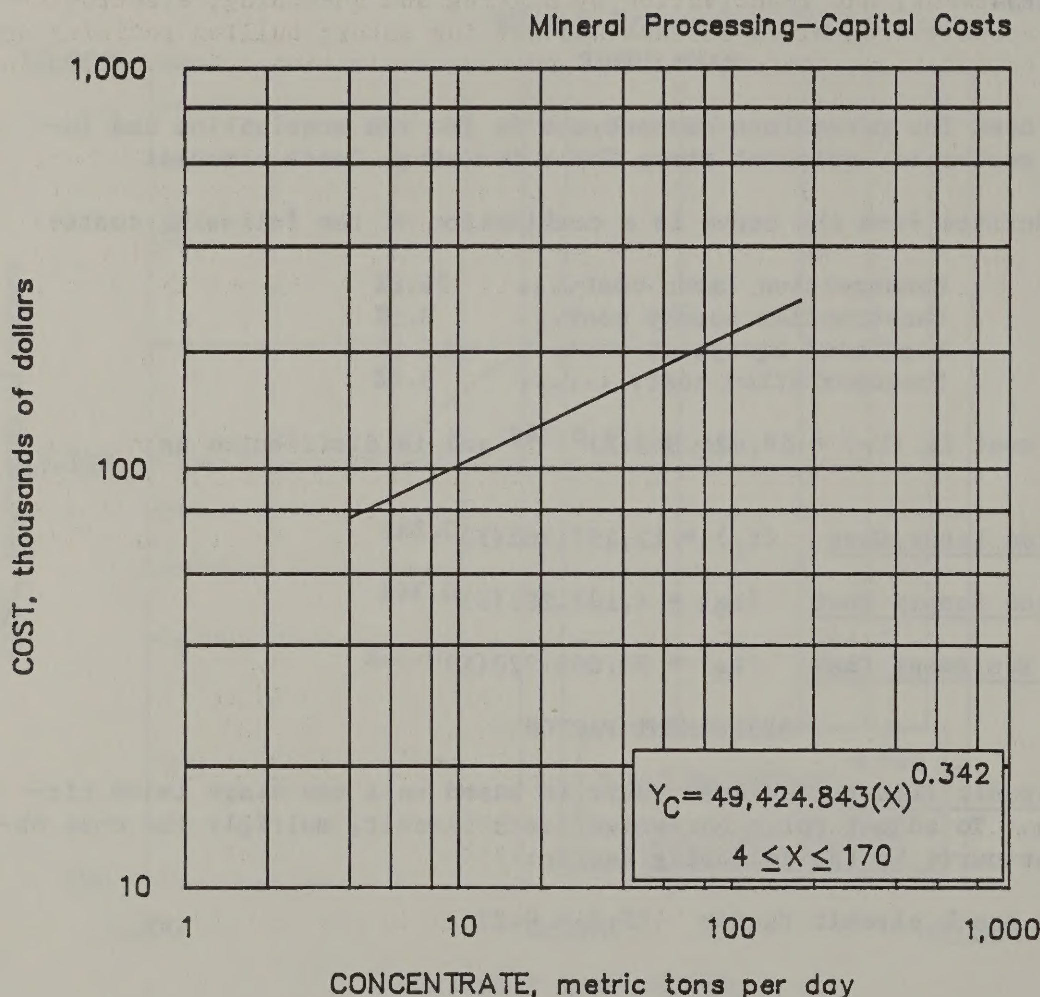
(S) Construction Supply Cost $(Y_S) = 4{,}102.262(X)^{0.342}$

(E) Purchased Equipment Cost $(Y_E) = 33{,}065.220(X)^{0.342}$

ADJUSTMENT FACTOR

One-Stage Leach Circuit Factor The base curve is based on a two-stage leach circuit operation. To adjust for a one-stage leach circuit, multiply the cost obtained from the curve by the following factor:

One-stage leach circuit factor $(F_1) = 0.22$



6.1.5.1.4. Acid leaching
PYROCHLORE

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.1.5. LEACHING CARBON-IN-PULP

The capital cost for the carbon-in-pulp (CIP) cyanide leaching process includes acquisition and installation of all equipment, including pumps, piping, wiring, carbon inventory, etc., necessary to provide thickening; leaching; wood-chip and trash removal screening; carbon adsorption, countercurrent transfer, screening, Zadra-type stripping, acid treatment, and reactivation by heating and quenching; electrowinning; scavenger recovery from bleed streams and tailing water; bullion refining and casting; and instrumentation, control-system, and computerization. Comminution and tailings disposal costs are not included.

The curve is not applicable to conventional cyanide agitation leaching with Merrill-Crowe precipitation; preagglomeration of ores; carbon-in-leach; preoxidation of carbonaceous or graphitic ores; carbon in column; autoclave or pressure leaching; amalgamation; high-intensity leaching circuitry; vat, heap, or dump leaching; or leaching with lixiviants other than cyanide, such as thiourea, thiosulfate, or aqueous chlorine.

BASE CURVE

The total cost is based on a single cost curve having an adjusted feed rate (X), in dry metric tons per day. The curve is valid for operations between 300 and 2,200 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition and installation of the equipment described above. No allowance is made for precious metal lockup in solution or on the carbon.

The cost curve is a combination of the following:

	Small (300 to 1,100 mtpd)	Large (1,100 to 2,200 mtpd)
Construction labor cost........	35%	14%
Construction supply cost.......	30%	23%
Purchased equipment cost.......	35%	54%

The total capital cost is $(Y_C) = 85{,}471.000(X)^{0.617}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ SMALL}) = 29{,}914.850(X)^{0.617}$
(S) Construction Supply Cost $(Y_{S\ SMALL}) = 25{,}641.300(X)^{0.617}$
(E) Purchased Equipment Cost $(Y_{E\ SMALL}) = 29{,}914.850(X)^{0.617}$

(L) Construction Labor Cost $(Y_{L\ LARGE}) = 11{,}965.940(X)^{0.617}$
(S) Construction Supply Cost $(Y_{S\ LARGE}) = 27{,}350.720(X)^{0.617}$
(E) Purchased Equipment Cost $(Y_{E\ LARGE}) = 46{,}154.340(X)^{0.617}$

ADJUSTMENT FACTORS

Carbon-in-Leach Plant Cost The cost of a similarily sized carbon-in-leach (CIL) plant may be calculated by the following equation:

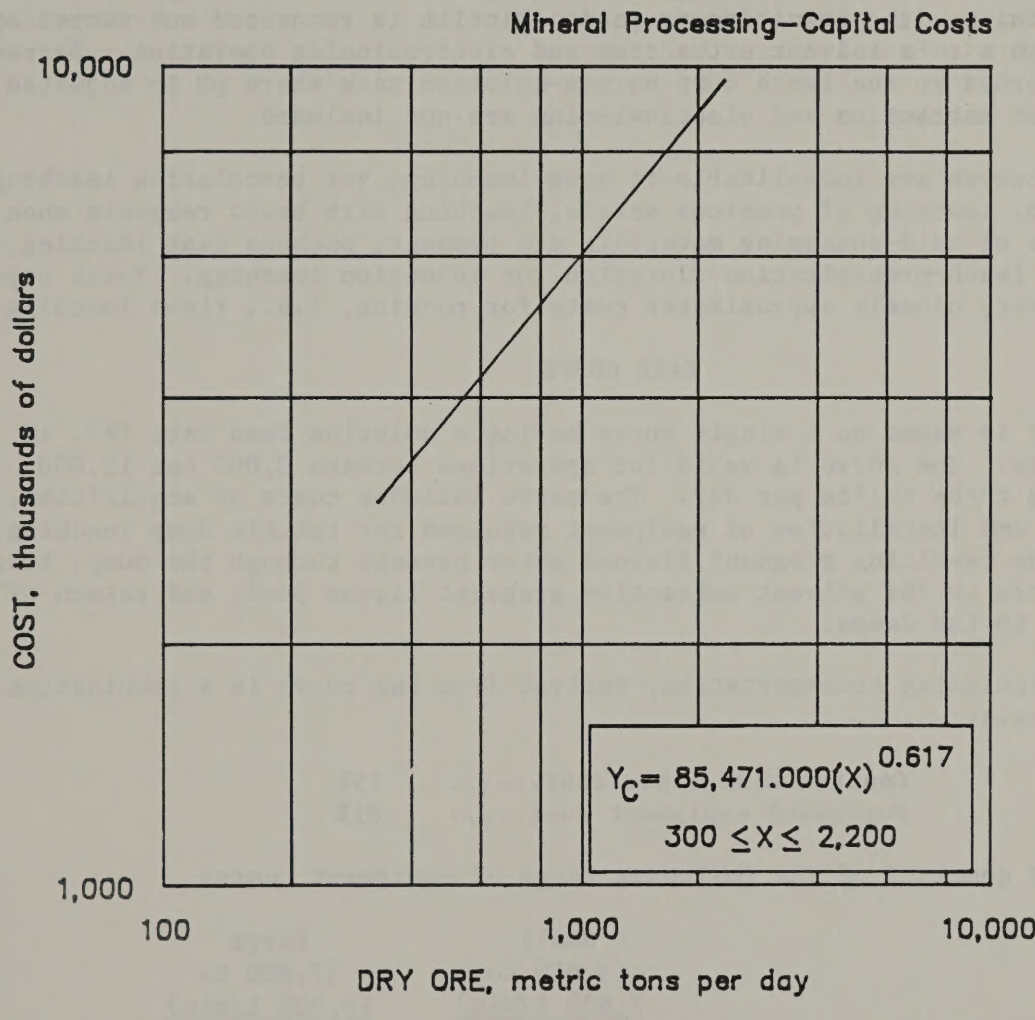
Carbon-in-leach plant cost $(Y_I) = 0.750(Y_C)$
where
(Y_C) = capital cost determined from the base curve.

Heap Leach Cost The capital cost of the facilities needed for auxiliary heap leaching process can be estimated to plus or minus 25% in average 1984 dollars[1]. The basic equation applies to operations greater than 900 mtpd and includes pads, ponds, piping, pumps, and a Merrill-Crowe or carbon adsorption recovery plant. Excluded are the costs of exploration, infrastructure (roads, water, etc.), preproduction stripping costs (for open pit mines), mining equipment, crushing-agglomeration equipment, and reclamation.

The total capital cost of heap leaching facilities may be calculated by the following equation:

Heap leach cost (Y_H) = (\$1200 to \$1400)(X)
where X = ore processed, in metric tons per day.

[1]Callicutt, W. W. Economic Aspects of Heap Leaching. Paper in Evaluation, Design, and Operation of Precious Metal Heap Leaching Projects, coordinated by D. J. A. Van Zyl (Soc. of Min. Eng. Fall Meeting and Exhibit, Albuquerque, NM, Oct. 13-15, 1985). Soc. of Min. Eng., 1985, pp. 39-66.



6.1.5.1.5. Leaching
CARBON—IN—PULP

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.1.6. LEACHING
COPPER DUMP

Capital costs for copper dump leaching by trickle-spray-leaching to enhance percolation assumes no clearing costs or auxiliary facilities for recovery of byproducts such as uranium or cobalt. A leach time of 6 months is assumed with 2 months following being allowed for dump "resting" with equipment left in place prior to resumption of leaching. The resulting pregnant solution is recovered and pumped approximately 3,000 m to a solvent extraction and electrowinning operation. Barren solution is returned to the leach dump barren-solution tank where pH is adjusted. Costs for solvent extraction and electrowinning are not included.

The dump leach curves are inapplicable to heap leaching, vat percolation leaching, in situ leaching, leaching of precious metals, leaching with basic reagents when large quantities of acid-consuming materials are present, pachuca tank leaching, slime leaching, leach-precipitation-flotation, or injection leaching. Total capital cost, however, closely approximates costs for ponding, i.e., flood leaching.

BASE CURVE

The capital cost is based on a single curve having a solution feed rate (X), in liters per minute. The curve is valid for operations between 3,000 and 12,000 L/min, operating three shifts per day. The curve includes costs of acquisition, transportation, and installation of equipment required for trickle dump leaching, collection of the resulting pregnant liquors after passage through the dump, transfer of the liquors to the solvent extraction pregnant liquor pond, and return of barren solution to the dumps.

The final cost including transportation, derived from the curve is a combination of the following costs:

Construction labor cost......	19%
Purchased equipment cost.....	81%

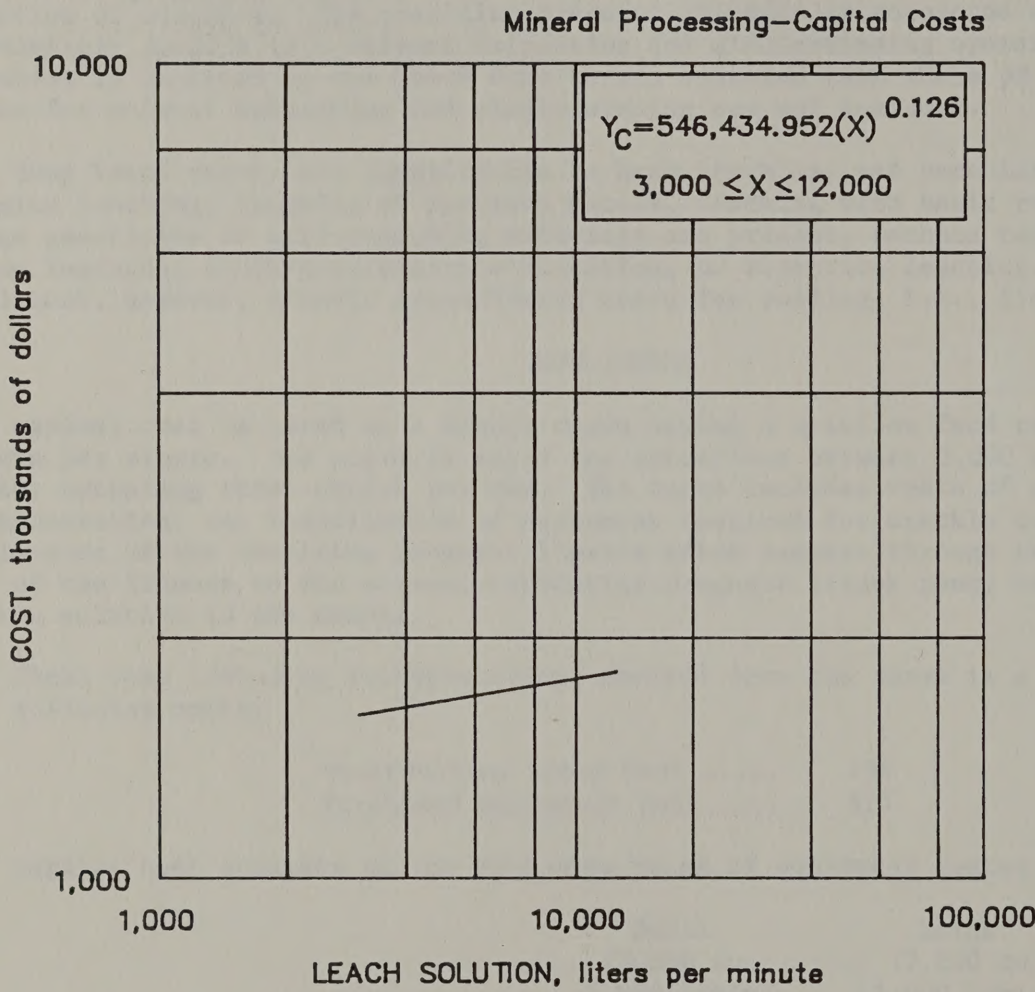
The capital cost consists of the following range of equipment costs:

	Small (3,000 to 7,800 L/min)	Large (7,800 to 12,000 L/min)
Pumps................	5%	8%
Pipe and couplings...	54%	55%
Pond.................	1%	1%
Tanks................	5%	5%
Vehicles.............	35%	31%

The total capital cost is $(Y_C) = 546,434.952(X)^{0.126}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 103,822.641(X)^{0.126}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 442,612.311(X)^{0.126}$



6.1.5.1.6. Leaching
COPPER DUMP

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.1.7. LEACHING

CONVENTIONAL CYANIDE LEACHING WITH MERRILL-CROWE PRECIPITATION

The capital cost for cyanide agitation leaching and recovery includes acquisition and installation of all equipment, including pumps, piping, instrumentation, wiring, etc., necessary for cyanide agitation leaching of 80% minus 200-mesh ore; countercurrent decantation; pregnant solution holding; pregnant solution final pressure clarification; deaeration including vacuum equipment; Merrill-Crowe zinc precipitation; precious metal pressure filtration; carbon column scavenger recovery from bleed streams and tailings return water; acid pretreatment of precipitates; and bullion refining and casting facilities. Comminution and tailings disposal costs are not included.

The curves cannot be applied to carbon-in-pulp (CIP) mills; preagglomeration of ores; carbon-in-leach; preoxidation of carbonaceous or graphitic ores; carbon-in-column; autoclave or pressure leaching; amalgamation; high-intensity leaching circuitry; vat, heap, or dump leaching; or leaching with lixiviants other than cyanide such as thiourea, thiosulfate, or aqueous chlorine. For lower throughputs, the curve is applicable to circuitry used for leaching of flotation and/or gravity concentrates.

Capital cost is not generally affected by variation in feed grade, as is the capital cost of similarly sized CIP mills, but is instead largely determined by the incoming feed flow rate.

BASE CURVE

The total cost is based on a single cost curve having an adjusted feed rate (X), in dry metric tons per day. The curve is valid for operations between 5 and 2,800 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition and installation of all equipment described above.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	22%
Construction supply cost.....	24%
Purchased equipment cost.....	54%

The total capital cost is $(Y) = 34,913.533(X)^{0.784}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 7,680.977(X)^{0.784}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 8,379.248(X)^{0.784}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 18,853.308(X)^{0.784}$

ADJUSTMENT FACTORS

<u>Heap Leach Cost</u> The capital cost of the facilities needed for auxiliary heap leaching process can be estimated to plus or minus 25% in average 1984

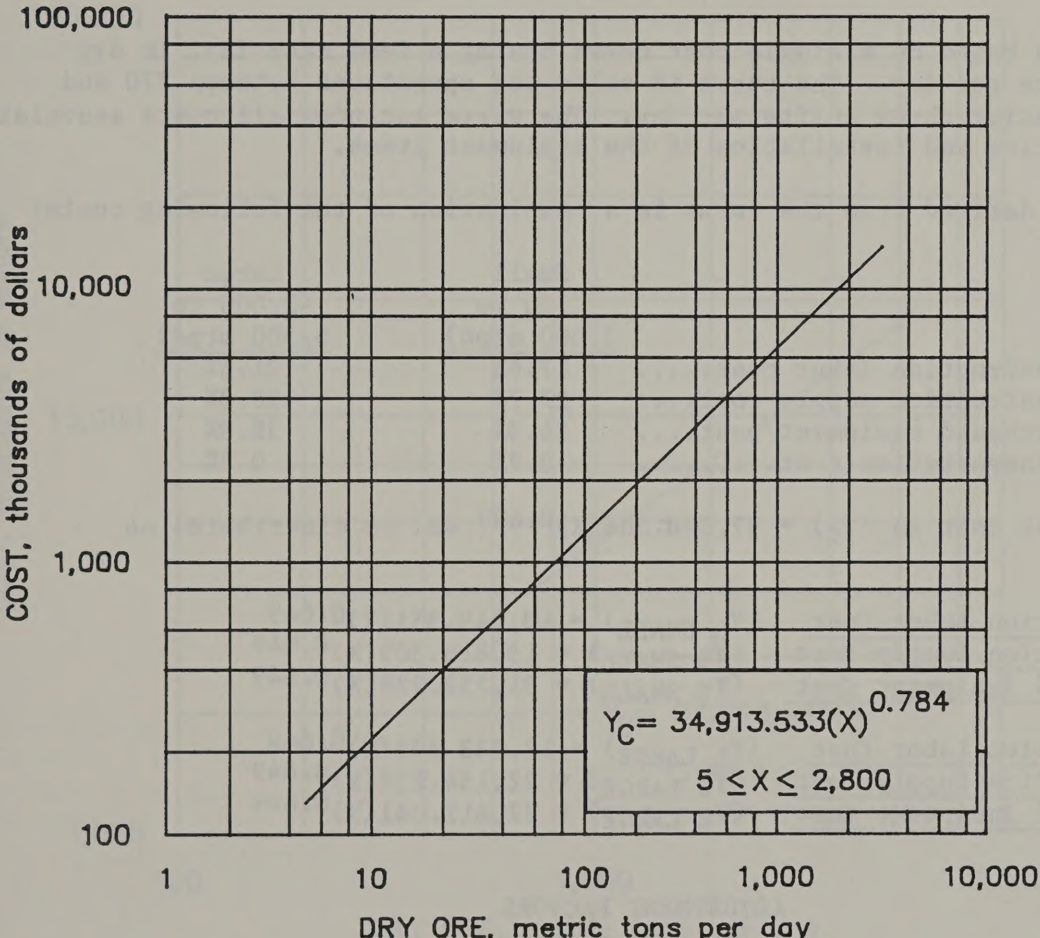
dollars[1]. The basic equation applies to operations greater than 900 mtpd and includes pads, ponds, piping, pumps, and a Merrill-Crowe or carbon adsorption recovery plant. Excluded are the costs of exploration, infrastructure (roads, water, etc.), preproduction stripping costs (for open pit mines), mining equipment, crushing-agglomeration equipment, and reclamation.

The total capital cost of heap leaching facilities may be calculated by the following equation:

Heap leach cost $(Y_H) = (\$1200 \text{ to } \$1400)(X)$
where X = ore processed, in metric tons per day.

[1]Callicutt, W. W. Economic Aspects of Heap Leaching. Paper in Evaluation, D-esign, and Operation of Precious Metal Heap Leaching Projects, coordinated by D. J. A. Van Zyl (Soc. of Min. Eng. Fall Meeting and Exhibit, Albuquerque, NM, Oct. 13-15, 1985). Soc. of Min. Eng., 1985, pp. 39-66.

Mineral Processing—Capital Costs



6.1.5.1.7. Leaching
CONVENTIONAL CYANIDE LEACHING WITH
MERRILL-CROWE PRECIPITATION

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.1.8. LEACHING
URANIUM

The capital cost for uranium leaching includes the acquisition and installation of equipment items following fine grinding through the production of uranium concentrate as yellowcake. The cost curve consists of the leaching, countercurrent decantation, solvent extraction, precipitation, and drying.

BASE CURVE

The total cost is based on a single cost curve having a feed rate (X), in dry metric tons of ore per day. The curve is valid for operations between 770 and 6,300 mtpd, operating three shifts per day. The curve includes all costs associated with the acquisition and installation of the equipment items.

The capital cost derived from the curve is a combination of the following costs:

	Small (770 to 2,000 mtpd)	Large (2,000 to 6,300 mtpd)
Construction labor cost.....	17.6%	21.6%
Construction supply cost....	27.7%	38.8%
Purchased equipment cost....	54.0%	38.9%
Transportation cost.........	0.7%	0.7%

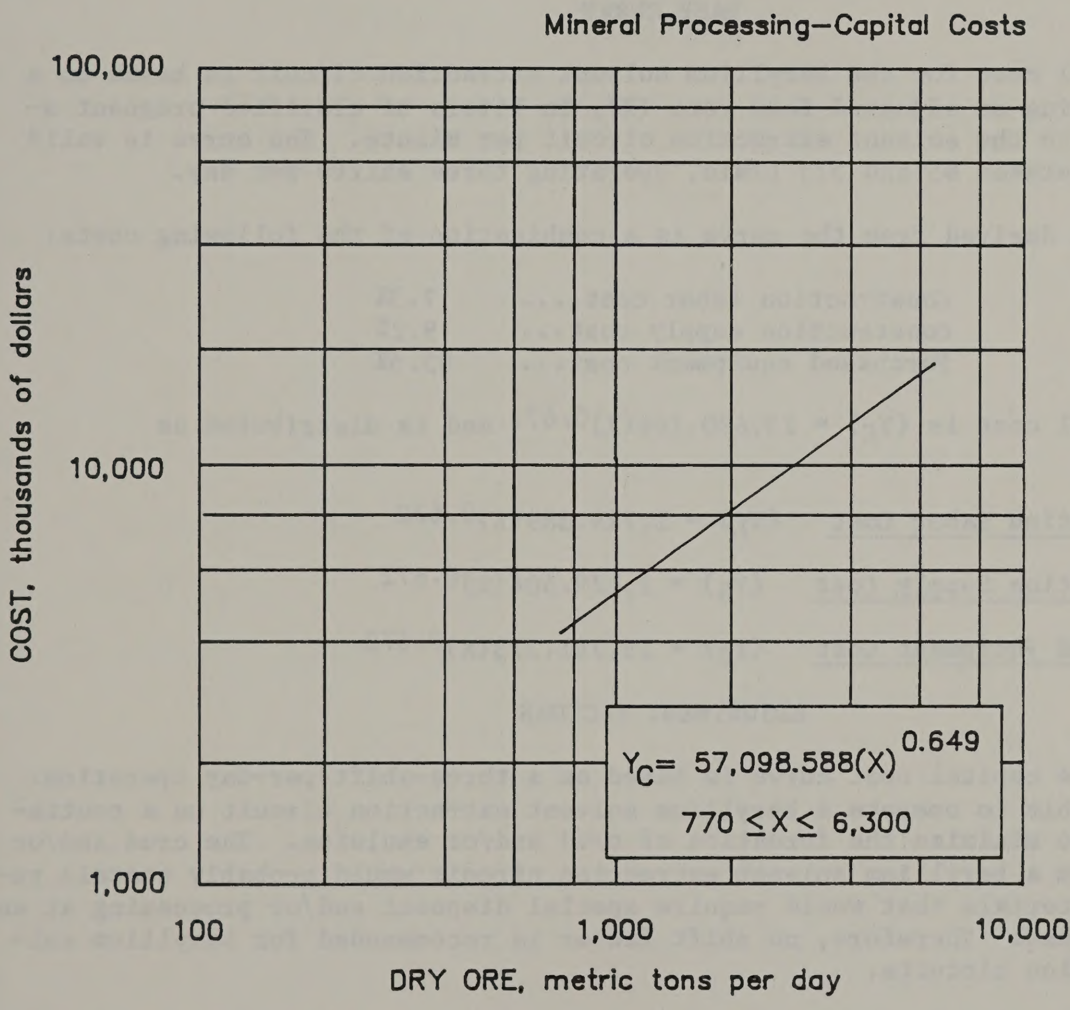
The total capital cost is $(Y_C) = 57{,}098.588(X)^{0.649}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ SMALL}) = 10{,}049.351(X)^{0.649}$
(S) Construction Supply Cost $(Y_{S\ SMALL}) = 15{,}816.309(X)^{0.649}$
(E) Purchased Equipment Cost $(Y_{E\ SMALL}) = 31{,}232.928(X)^{0.649}$

(L) Construction Labor Cost $(Y_{L\ LARGE}) = 12{,}333.295(X)^{0.649}$
(S) Construction Supply Cost $(Y_{S\ LARGE}) = 22{,}154.252(X)^{0.649}$
(E) Purchased Equipment Cost $(Y_{E\ LARGE}) = 22{,}611.041(X)^{0.649}$

ADJUSTMENT FACTORS

Shift Factor The curve is based on a three-shift-per-day operation. Typically, uranium milling operations are operations are operated on a continuous basis to maintain steady flow rates between the various circuits. No adjustment factor is recommended for uranium leaching.



6.1.5.1.8. Leaching
URANIUM

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.2.1. SOLVENT EXTRACTION BERYLLIUM

The capital cost includes the acquisition and installation of equipment items associated with the solvent extraction circuit for beryllium. Major equipment items include storage tanks, pumps, mixer-settlers, and mixer mechanisms.

BASE CURVE

The total capital cost for the beryllium solvent extraction circuit is based on a single curve having an adjusted feed rate (X), in liters of clarified pregnant aqueous solution to the solvent extraction circuit per minute. The curve is valid for operations between 85 and 575 L/min, operating three shifts per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	7.3%
Construction supply cost...	9.2%
Purchased equipment cost...	83.5%

The total capital cost is $(Y_C) = 23{,}690.266(X)^{0.672}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 1{,}729.389(X)^{0.672}$

(S) Construction Supply Cost $(Y_S) = 2{,}179.504(X)^{0.672}$

(E) Purchased Equipment Cost $(Y_E) = 19{,}781.373(X)^{0.672}$

ADJUSTMENT FACTORS

Shift Factor The capital cost curve is based on a three-shift-per-day operation. It is desirable to operate a beryllium solvent extraction circuit on a continuous basis to minimize the formation of crud and/or emulsion. The crud and/or emulsion from a beryllium solvent extraction circuit would probably contain radioactive materials that would require special disposal and/or processing at an additional cost. Therefore, no shift factor is recommended for beryllium solvent extraction circuits.

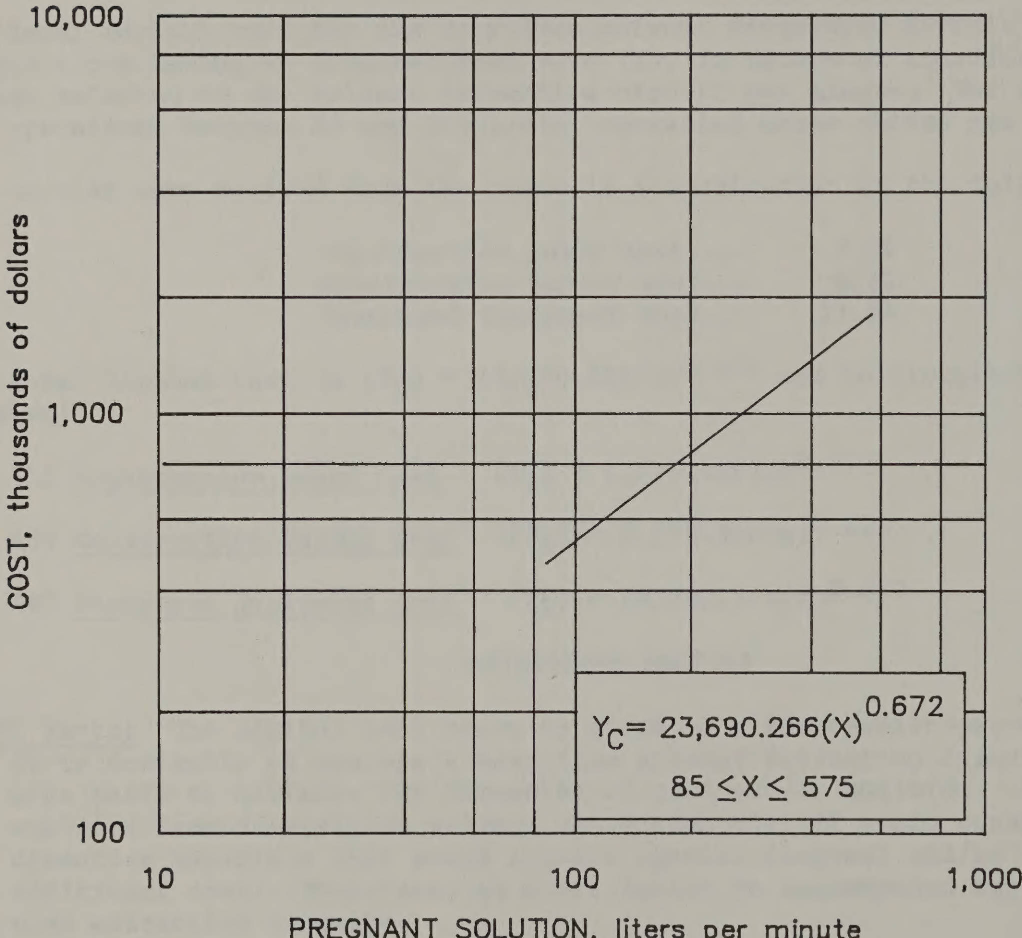
Number of Extraction Stages Factor The base curve is premised on the installation of seven extraction stages in the beryllium solvent extraction circuit. To adjust for a different number of extraction stages, multiply the cost obtained from the curve by the following factor:

Number of extraction stages factor $(F_E) = 0.326(E)^{0.576}$
where E = actual number of extraction stages.

Number of Stripping Stages Factor The base curve is premised on the installation of two stripping stages in the beryllium solvent extraction circuit. To adjust for a different number of stripping stages, multiply the cost obtained from the curve by the following factor:

Number of stripping stages factor $(F_S) = 0.883(S)^{0.180}$
where S = actual number of stripping stages.

Mineral Processing—Capital Costs



6.1.5.2.1. Solvent extraction
BERYLLIUM

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.5. HYDROMETALLURGY

6.1.5.2.2. SOLVENT EXTRACTION COPPER

The capital cost includes the acquisition and installation of equipment items associated with the solvent extraction circuit for copper. Major equipment items include storage tanks, pumps, mixer-settlers, and mixer mechanisms.

BASE CURVE

The capital cost curve is based on a single curve having an adjusted feed rate (X), in liters of clarified pregnant aqueous solution to the solvent extraction circuit per minute. The curve is valid for operations between 8,000 and 27,000 L/min, operating three shifts per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	25.3%
Construction supply cost...	51.4%
Purchased equipment cost...	22.9%
Transportation cost........	0.4%

The total capital cost is $(Y_C) = 382.979(X)^{0.955}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 96.894(X)^{0.955}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 196.851(X)^{0.955}$

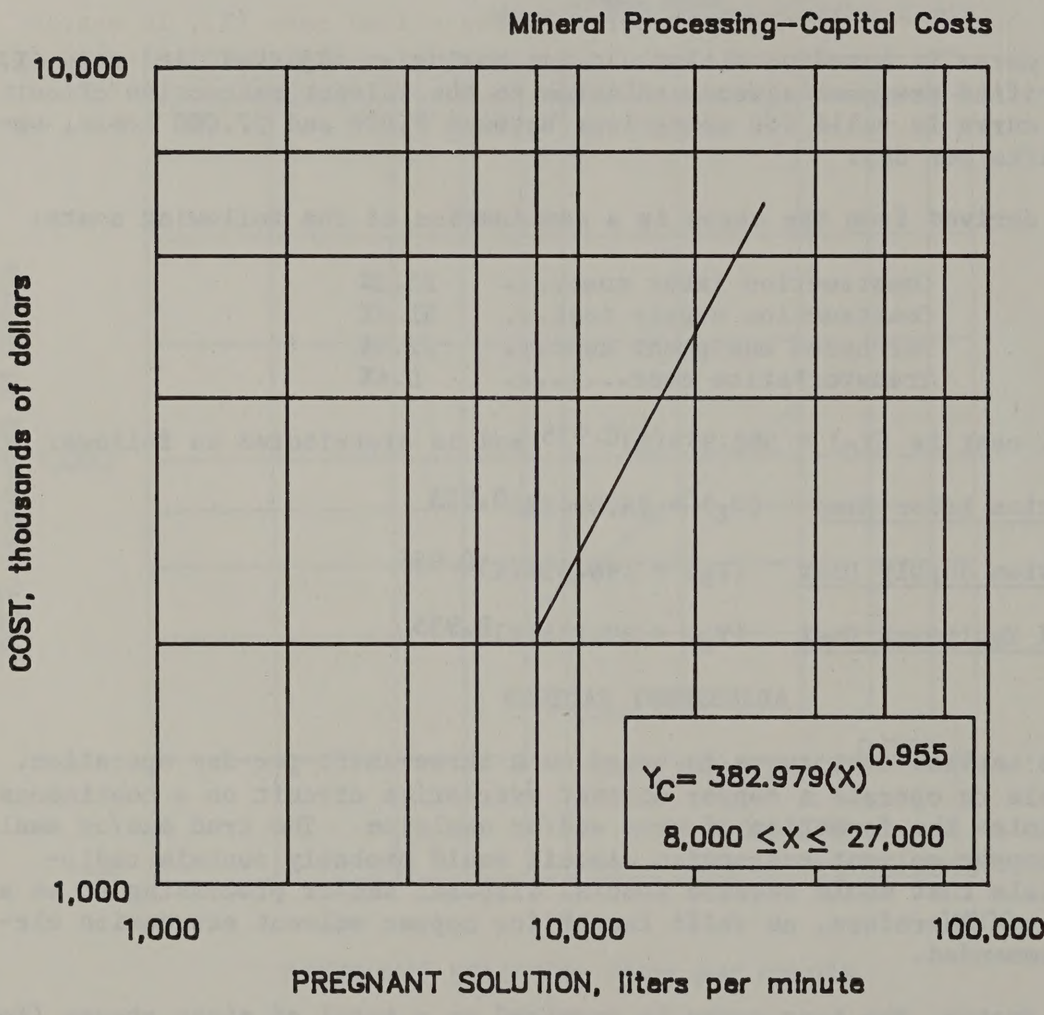
(E) <u>Purchased Equipment Cost</u> $(Y_E) = 89.234(X)^{0.955}$

ADJUSTMENT FACTORS

<u>Shift Factor</u> The capital cost curve is based on a three-shift-per-day operation. It is desirable to operate a copper solvent extraction circuit on a continuous basis to minimize the formation of crud and/or emulsion. The crud and/or emulsion from a copper solvent extraction circuit would probably contain radioactive materials that would require special disposal and/or processing at an additional cost. Therefore, no shift factor for copper solvent extraction circuits is recommended.

<u>Number of Stages Factor</u> The base curve is premised on a total of eight stages (four extraction and four stripping) in the solvent extraction circuit. To adjust for a different number of stages, multiply the cost obtained from the curve by the following factor:

Number of stages factor $(F_N) = 0.249(N)^{0.668}$
where N = total number of extraction and stripping stages.



6.1.5.2.2. Solvent extraction
COPPER

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.1. AMALGAMATION

The capital cost of amalgamation is for the acquisition and installation of equipment needed to process a gravity concentrate for the recovery of gold. The amalgamation circuit includes amalgamators and/or amalgamation plates.

BASE CURVE

The total cost is based on a single cost curve having a feed rate (X), in metric tons of feed material to the amalgamation circuit per day. The curve is valid for operations between 0.4 and 65.0 mtpd, operating one shift per day. The curve includes all costs associated with the acquisition and installation of the amalgamation circuit.

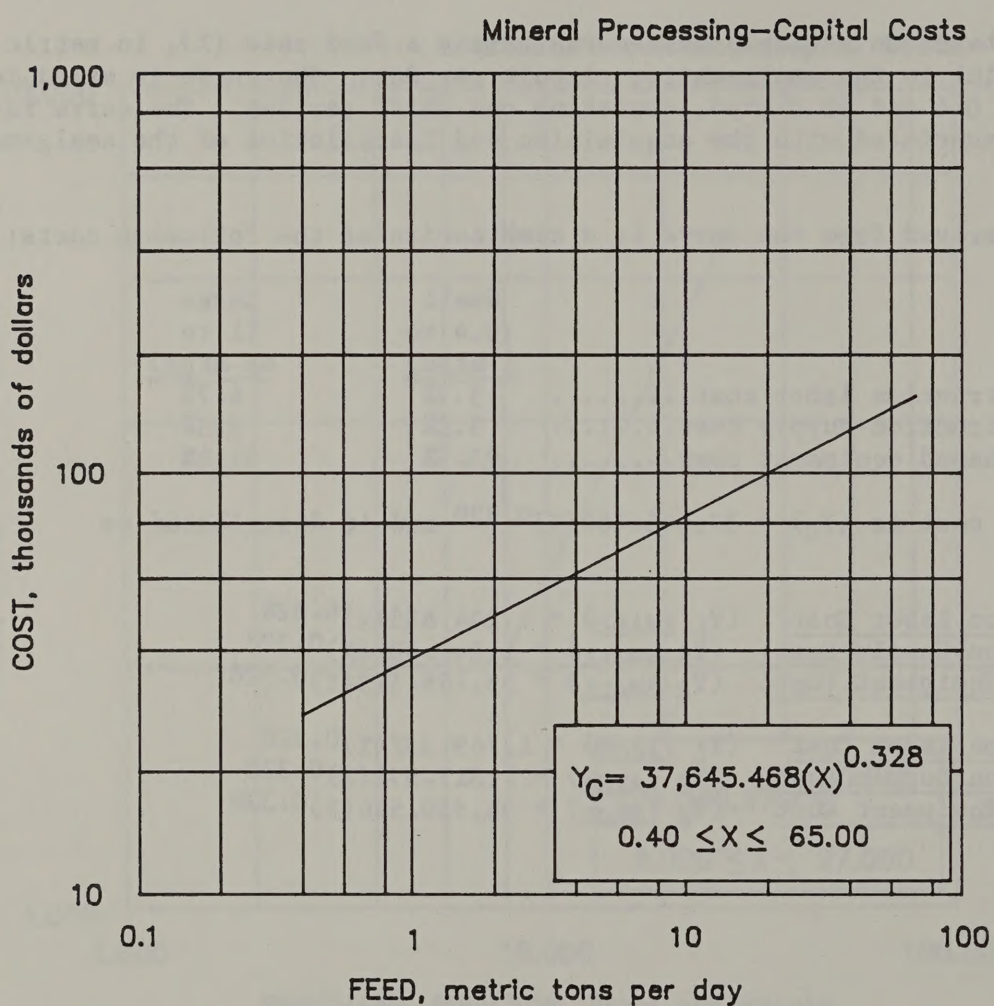
The capital cost derived from the curve is a combination of the following costs:

	Small (0.4 to 1 mtpd)	Large (1 to 65 mtpd)
Construction labor cost.........	3.2%	4.7%
Construction supply cost........	3.3%	3.5%
Purchased equipment cost........	93.5%	91.8%

The total capital cost is $(Y_C) = 37,645.468(X)^{0.328}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ SMALL}) = 1,204.655(X)^{0.328}$
(S) Construction Supply Cost $(Y_{S\ SMALL}) = 1,242.300(X)^{0.328}$
(E) Purchased Equipment Cost $(Y_{E\ SMALL}) = 35,198.513(X)^{0.328}$

(L) Construction Labor Cost $(Y_{L\ LARGE}) = 1,769.337(X)^{0.328}$
(S) Construction Supply Cost $(Y_{S\ LARGE}) = 1,317.591(X)^{0.328}$
(E) Purchased Equipment Cost $(Y_{E\ LARGE}) = 34,558.540(X)^{0.328}$



6.1.6.1. Amalgamation

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.2.1. BRINE RECOVERY LITHIUM (WELLS)

The capital cost includes the acquisition and installation of equipment items associated with the brine recovery system.

BASE CURVE

The total capital cost for a lithium brine recovery system is based on a single curve having an adjusted feed rate (X), in liters of lithium-bearing solution per minute. The curve is valid for operations between 1,300 and 9,700 L/min of brine solution, operating three shifts per day. The curve is for the acquisition and installation of the purchased equipment items including pumps, solar evaporation ponds, and mobile equipment. The capital cost curve does not include the cost of site preparation for the solar evaporation ponds. This cost should be estimated using clearing (section 6.1.8.1).. The amount of area, in hectares, for site preparation is calculated using the following equation:

Site preparation area $(A) = 19{,}793.209-[83.024(N)]$
where N = net evaporation rate, in centimeters per year.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	32.8%
Construction supply cost...	55.1%
Purchased equipment cost...	12.0%
Transportation cost........	0.1%

The total capital cost is $(Y_C) = 5{,}696.547(X)^{0.929}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 1{,}868.467(X)^{0.929}$

(S) Construction Supply Cost $(Y_S) = 3{,}138.797(X)^{0.929}$

(E) Purchased Equipment Cost $(Y_E) = 689.283(X)^{0.929}$

ADJUSTMENT FACTORS

Well Depth Factor The base curve is premised on an average well depth of 150 m. To adjust for a different average depth, multiply the cost obtained from the curve by the following factor:

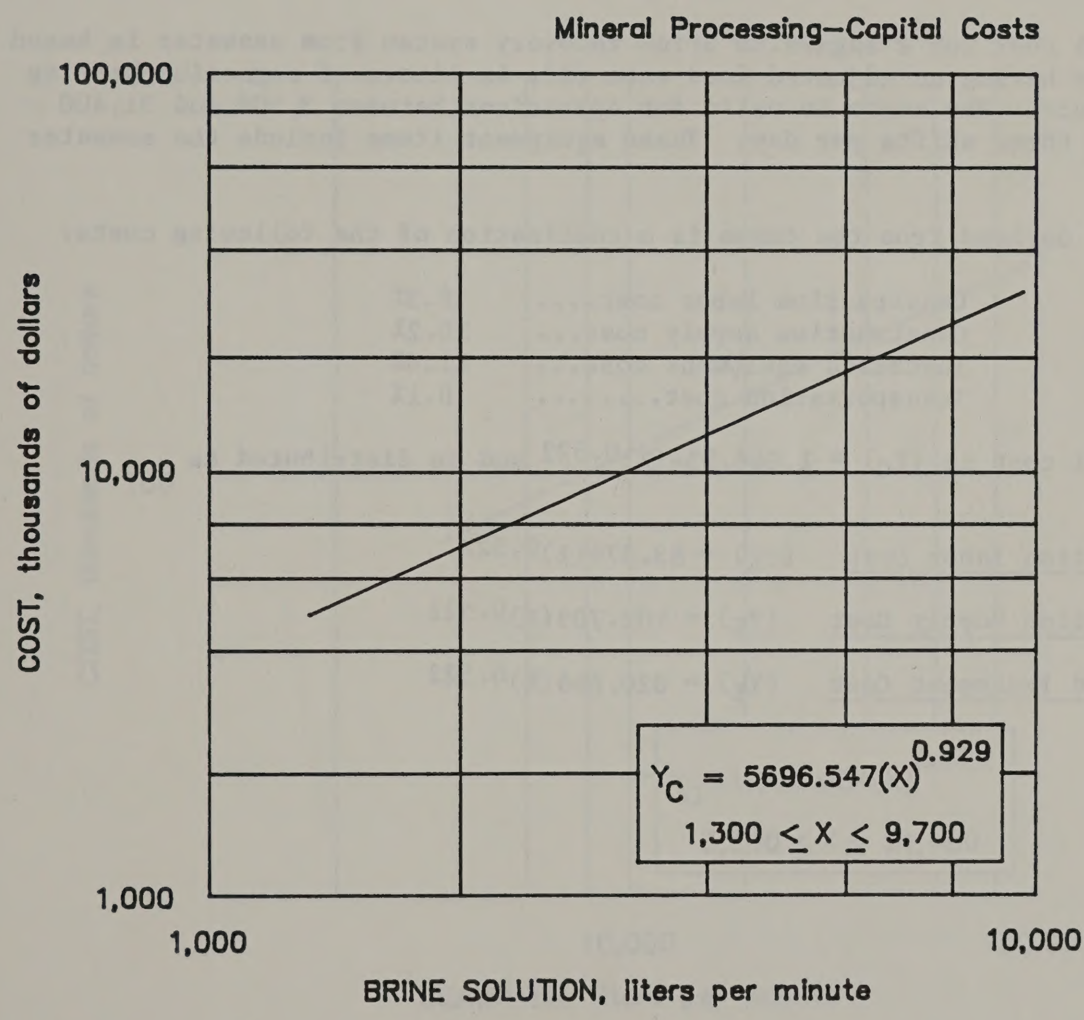
Well depth factor $(F_D) = 0.00250(D)+0.626$
where D = well depth, in meters.

Net Evaporation Rate Factor The base curve is premised on a net evaporation rate of 119.4 cm/yr. To adjust for a different net evaporation rate, multiply the cost obtained from the curve by the following factor:

Net evaporation rate factor $(F_E) = 1.30-[0.00251(E)]$
where E = net evaporation rate in centimeters per year

<u>Solar Evaporation Pond Liner Factor</u> The base curve is premised on the installation of unlined solar evaporation ponds. To adjust the base curve for the installation of a synthetic liner, multiply the cost obtained from the curve by the following factor:

Solar evaporation pond liner factor $(F_L) = 4.6$



6.1.6.2.1. Brine recovery
LITHIUM (WELLS)

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.2.2. BRINE RECOVERY
MAGNESIUM (SEAWATER)

The capital cost includes the acquisition and installation of equipment items associated with the brine recovery system.

BASE CURVE

The total capital cost for a magnesium brine recovery system from seawater is based on a single curve having an adjusted feed rate (X), in liters of magnesium-bearing seawater per minute. The curve is valid for operations between 3,500 and 91,400 L/min, operating three shifts per day. These equipment items include the seawater pumps and pier.

The capital cost derived from the curve is a combination of the following costs:

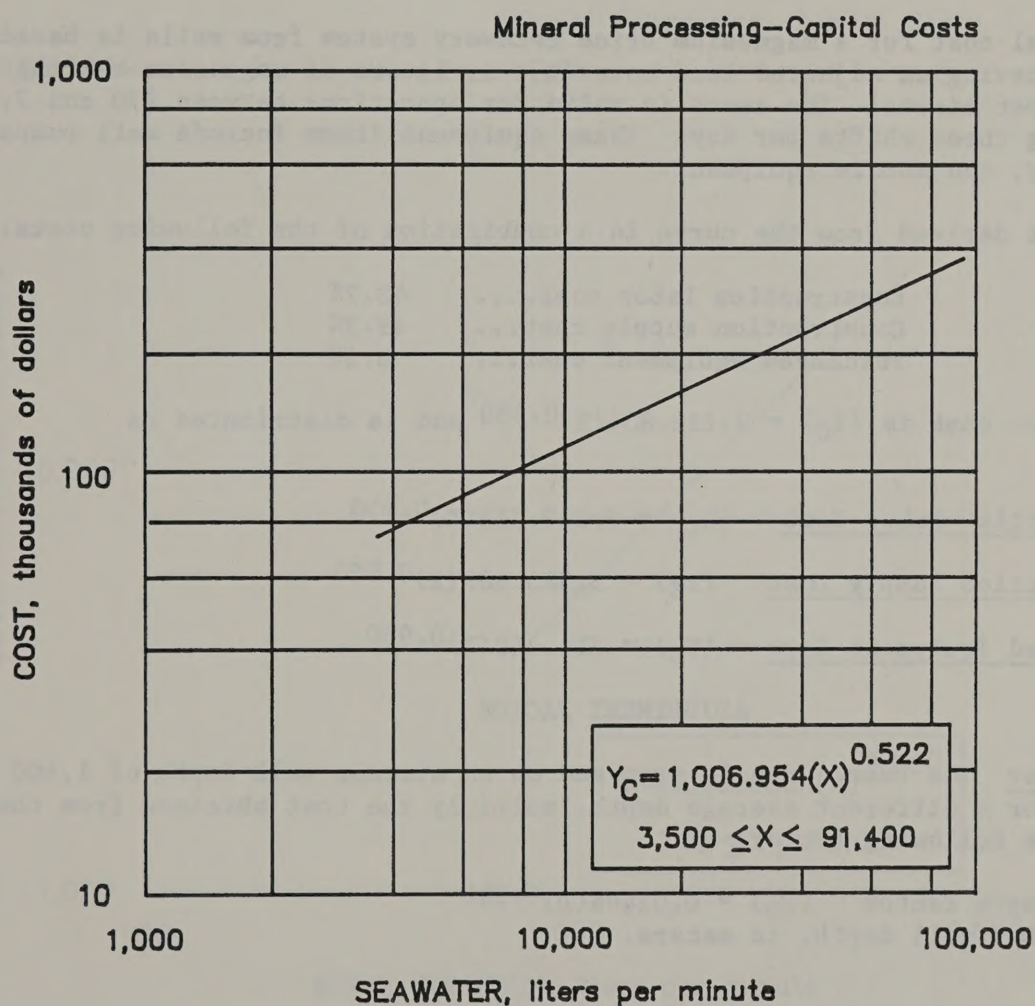
Construction labor cost....	8.3%
Construction supply cost...	10.2%
Purchased equipment cost...	81.4%
Transportation cost........	0.1%

The total capital cost is $(Y_C) = 1{,}006.954(X)^{0.522}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 83.579(X)^{0.522}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 102.709(X)^{0.522}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 820.666(X)^{0.522}$



6.1.6.2.2. Brine recovery
MAGNESIUM (SEAWATER)

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.2.3. BRINE RECOVERY MAGNESIUM (WELLS)

The capital cost includes the acquisition and installation of equipment items associated with the brine recovery system.

BASE CURVE

The total capital cost for a magnesium brine recovery system from wells is based on a single curve having an adjusted feed rate (X), in liters of magnesium-bearing brine solution per minute. The curve is valid for operations between 770 and 7,000 L/min, operating three shifts per day. These equipment items include well pumps, storage facility, and mobile equipment.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	42.2%
Construction supply cost...	49.3%
Purchased equipment cost...	8.5%

The total capital cost is $(Y_C) = 7,228.804(X)^{0.950}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 3,050.555(X)^{0.950}$

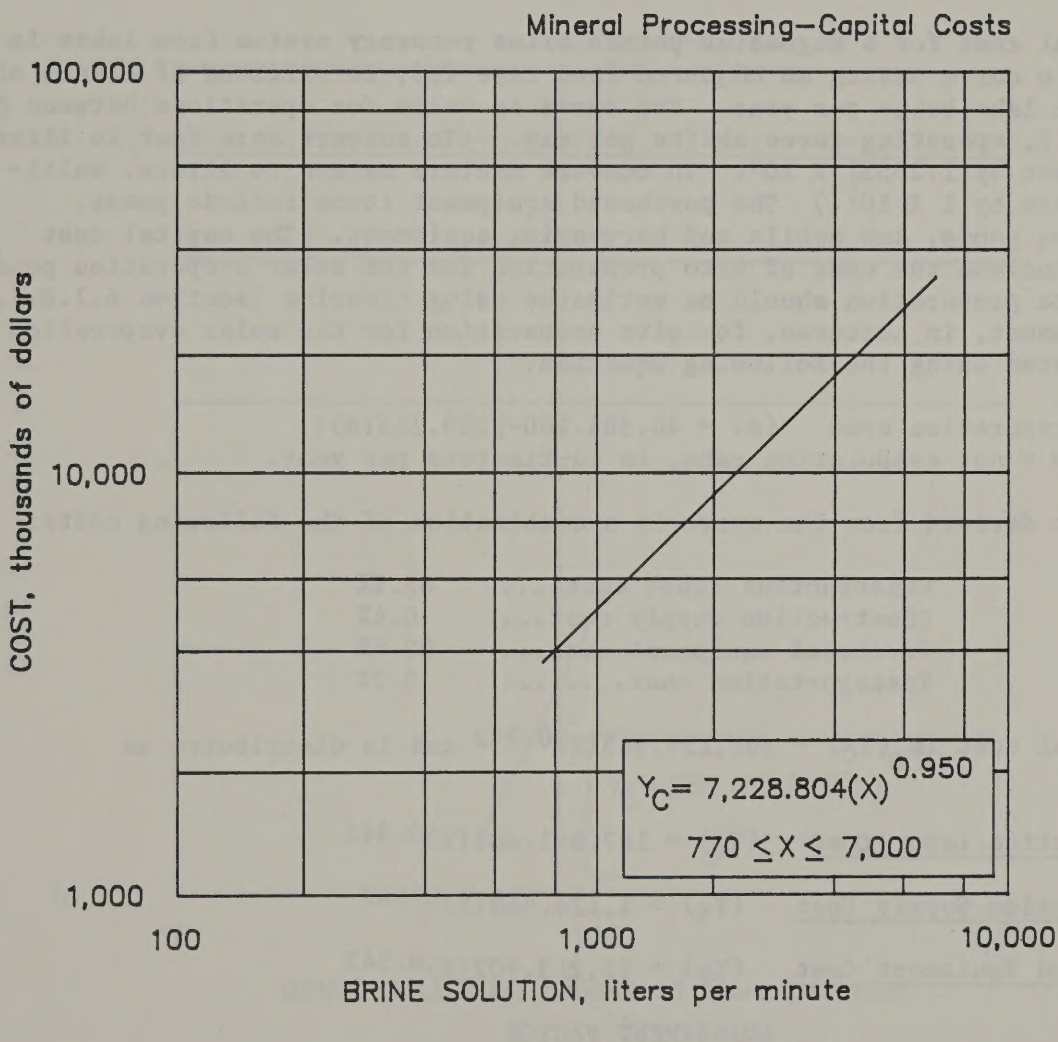
(S) <u>Construction Supply Cost</u> $(Y_S) = 3,563.800(X)^{0.950}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 614.448(X)^{0.950}$

ADJUSTMENT FACTOR

<u>Well Depth Factor</u> The base curve is premised on an average well depth of 1,400 m. To adjust for a different average depth, multiply the cost obtained from the curve by the following factor:

Well depth factor $(F_D) = 0.02486(D)^{0.510}$
where D = well depth, in meters.



6.1.6.2.3. Brine recovery
MAGNESIUM (WELLS)

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.2.4. BRINE RECOVERY MAGNESIUM/POTASH (LAKES)

The capital cost includes the acquisition and installation of equipment items associated with the brine recovery system.

BASE CURVE

The total capital cost for a magnesium-potash brine recovery system from lakes is based on a single curve having an adjusted feed rate (X), in billions of liters of magnesium-potash lake brine per year. The curve is valid for operations between 50 and 105 billion L, operating three shifts per day. (To convert acre feet to liters, multiply acre feet by 1.23331×10^6. To convert hectare meters to liters, multiply hectare meters by 1×10^7.) The purchased equipment items include pumps, solar evaporation ponds, and mobile and harvesting equipment. The capital cost curve does not include the cost of site preparation for the solar evaporation ponds. The cost for site preparation should be estimated using clearing (section 6.1.8.1.). The area requirement, in hectares, for site preparation for the solar evaporation ponds is calculated using the following equation:

Site preparation area $(A) = 46{,}584.200-[229.253(N)]$
where N = net evaporation rate, in centimeters per year.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	66.8%
Construction supply cost...	0.4%
Purchased equipment cost...	32.6%
Transportation cost........	0.2%

The total capital cost is $(Y_C) = 281{,}139.945(X)^{0.942}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 187{,}801.483(X)^{0.942}$

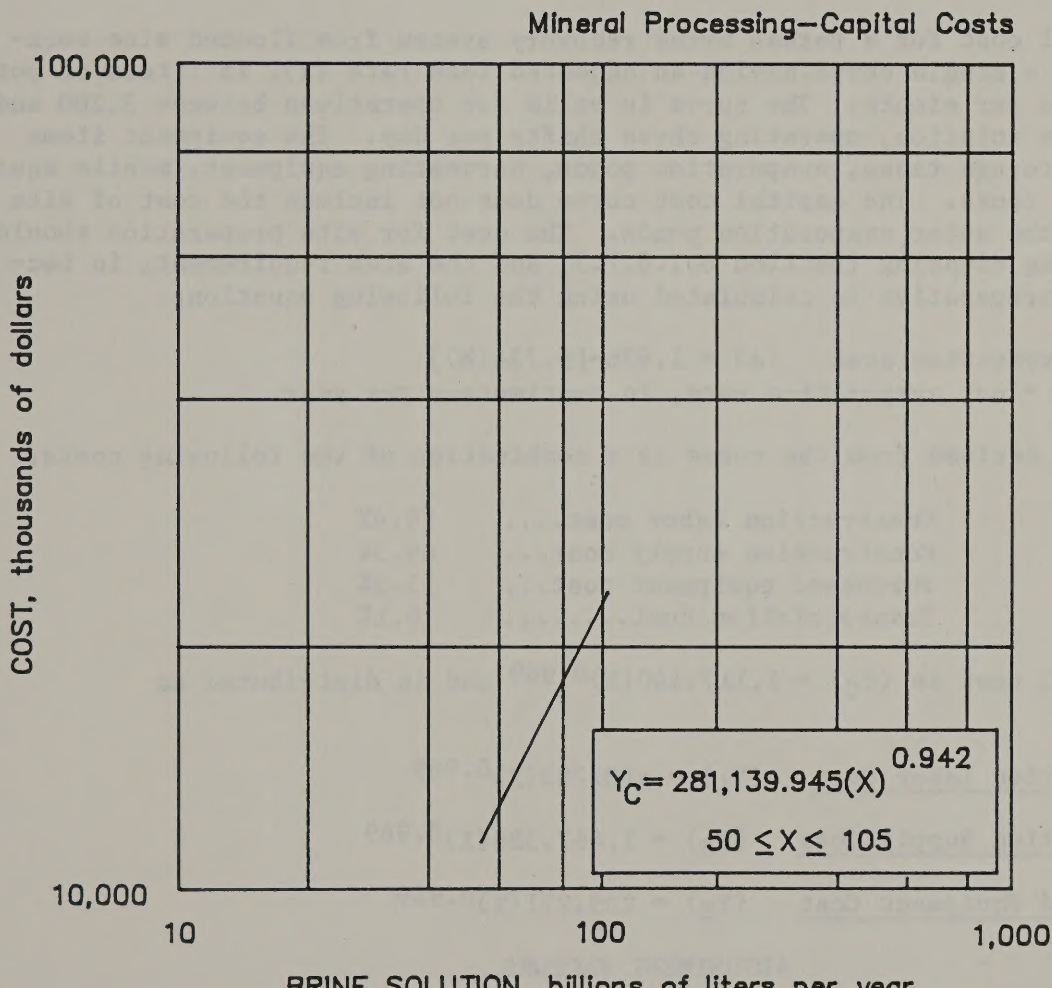
(S) Construction Supply Cost $(Y_S) = 1{,}124.560(X)^{0.942}$

(E) Purchased Equipment Cost $(Y_E) = 92{,}213.902(X)^{0.942}$

ADJUSTMENT FACTOR

Net Evaporation Rate Factor The base curve is premised on a net evaporation rate of 101.6 cm/yr. To adjust for a different net evaporation rate, multiply the cost obtained from the curve by the following factor:

Net evaporation rate factor $(F_E) = 1.676-[0.00665(E)]$
where E = net evaporation rate, in centimeters per year.



6.1.6.2.4. Brine recovery
MAGNESIUM/POTASH (LAKES)

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.2.5. BRINE RECOVERY POTASH (FLOODED MINE)

The capital cost includes the acquisition and installation of equipment items associated with the brine recovery system.

BASE CURVE

The total capital cost for a potash brine recovery system from flooded mine workings is based on a single curve having an adjusted feed rate (X), in liters of potash-bearing brine per minute. The curve is valid for operations between 3,200 and 13,000 L of brine solution, operating three shifts per day. The equipment items include pumps, storage tanks, evaporation ponds, harvesting equipment, mobile equipment, and slurry tanks. The capital cost curve does not include the cost of site preparation for the solar evaporation ponds. The cost for site preparation should be estimated using clearing (section 6.1.8.1.), and the area requirement, in hectares, for site preparation is calculated using the following equation:

Site preparation area $(A) = 1{,}976-[9.724(N)]$
where N = net evaporation rate, in centimeters per year.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	19.4%
Construction supply cost...	69.3%
Purchased equipment cost...	11.2%
Transportation cost........	0.1%

The total capital cost is $(Y_C) = 2{,}117.440(X)^{0.969}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 410.783(X)^{0.969}$

(S) Construction Supply Cost $(Y_S) = 1{,}467.386(X)^{0.969}$

(E) Purchased Equipment Cost $(Y_E) = 239.271(X)^{0.969}$

ADJUSTMENT FACTORS

Pumping Head Factor The base curve is premised on an average pumping head of 244 m. To adjust for a different average pump head, multiply the cost obtained from the curve by the following factor:

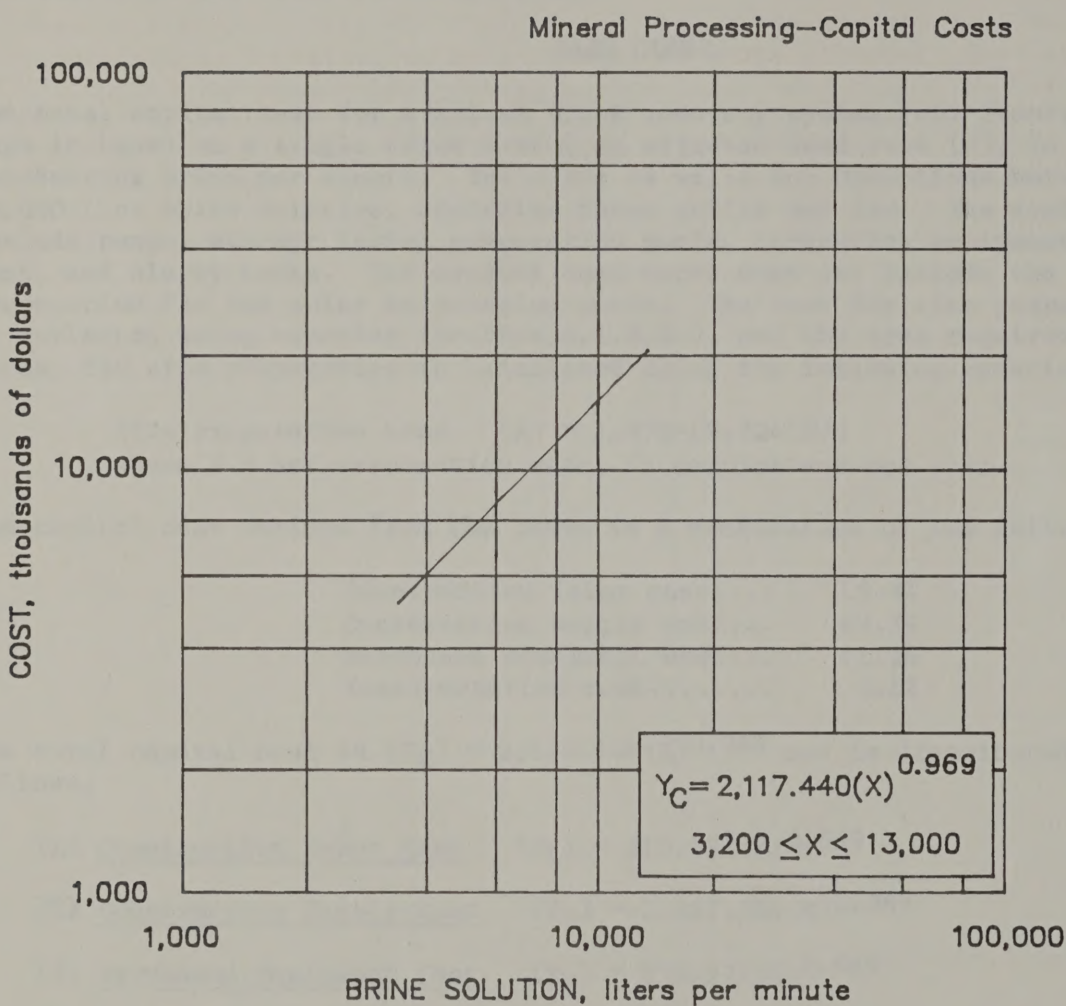
Pumping head factor $(F_H) = 0.0000172(H)+0.996$
where H = pumping head, in meters.

Net Evaporation Rate Factor The base curve is premised on a net evaporation rate of 101.6 cm/yr. To adjust for a different net evaporation rate, multiply the cost obtained from the curve by the following factor:

Net evaporation rate factor $(F_E) = 1.803-[0.0079(E)]$
where E = net evaporation rate, in centimeters per year.

<u>Evaporation Pond Liner Factor</u> The base curve is premised on the installation of a synthetic liner in the solar evaporation ponds. To adjust for no synthetic liner in the solar evaporation ponds, multiply the cost obtained from the curve by the following factor:

Evaporation pond liner factor $(F_L) = 0.206$



6.1.6.2.5. Brine recovery
POTASH (FLOODED MINE)

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.3. CALCINATION (ROTARY KILN)

Capital costs for rotary-kiln operations are for the acquisition and installation of equipment for calcining (or applying high heat to) limestone or other ores or materials, using appropriate adjustment factors. This section starts with conveyance of the crushed limestone or other feed material to the kiln, includes calcination using coal as fuel, and ends after conveyance from the kiln. A special section is included for estimating the cost of storage and load-out of the product. The total capital cost is based on a single curve having an adjusted feed rate (X), in metric tons per day. The curve is valid for operations between 100 and 6,000 mtpd, operating three shifts per day.

BASE CURVE

Major items of equipment are rotary refractory-lined kilns, product cooler, stone and coal weigh belts, coal ball mill, burner, fans, fabric dust collector, belt and screw conveyors, steel storage bins (dust and coal), and coal handling equipment.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	44%
Construction supply cost.....	22%
Purchased equipment cost.....	34%

The capital cost consists of the following typical range of equipment costs:

	Small (100 to 750 mtpd)	Large (750 to 6,000 mtpd)
Kilns (and related equipment).....	83%	92%
Conveyors and elevators...........	5%	2%
Storage bins......................	10%	5%
Front-end loader..................	2%	1%

The total capital cost is $(Y_C) = 95,349.610(X)^{0.759}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 41,953.828(X)^{0.759}$

(S) Construction Supply Cost $(Y_S) = 20,976.914(X)^{0.759}$

(E) Purchased Equipment Cost $(Y_E) = 32,418.868(X)^{0.759}$

ADJUSTMENT FACTORS

Shift Factor The curve is based on a three shift per day operation. Because it would be impractical to operate less than 24 hours per day (due to the large heat losses connected with starting up and shutting down), no shift adjustment factors should be used.

Fuel Factor If natural gas is used as a fuel instead of coal, multiply the cost obtained from the curve by the following factor:

Fuel factor $(F_{F\ NATURAL\ GAS}) = 0.949$

If fuel oil is used instead of coal, multiply the cost obtained from the curve by the following factor:

Fuel factor $(F_{F\ FUEL\ OIL}) = 0.969$

Length-to-Diameter Factor To adjust the capital cost for kiln length-to-diameter (L/D) ratios different than 32, multiply the cost obtained from the curve by the following factor (see the ratio, length-diameter, column of the following tabulation for ratios for various commodities):

Length-to-diameter factor $(F_{L/D}) = 0.696(L/D)^{0.104}$

STORAGE AND LOAD-OUT OF PRODUCT

The capital cost for storage and load-out of the product from the kilns includes the acquisition and installation of equipment to receive, store, and load-out the product. The total cost is based on a single curve having a product storage, load-out rate (X), in metric tons per day. The curve is valid for operations between 100 and 6,000 mtpd, operating three shifts per day.

Major items include belt conveyors, bucket elevators, vibrating screens, product crushers, and steel storage bins. The costs are distributed as follows:

Construction labor cost......	22%
Construction supply cost.....	11%
Purchased equipment cost.....	67%

The capital cost consists of the following typical range of equipment costs:

Conveyors (belt).......	10%
Elevators (bucket).....	2%
Screens................	1%
Crushers (hammermill)..	4%
Bins (steel)...........	83%

The total capital cost is $(Y_C) = 147{,}957.493(X)^{0.368}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 32{,}550.649(X)^{0.368}$

(S) Construction Supply Cost $(Y_S) = 16{,}275.324(X)^{0.368}$

(E) Purchased Equipment Cost $(Y_E) = 99{,}131.520(X)^{0.368}$

Rotary kiln calcination - Feed and product characteristics and cost factors

Product and feed or reaction	Normal moisture in feed, %	Fuel rate[1] Btu/mt product	Fuel cost multi-plier[2]	Length diameter ratio[3] (L/D)	Specific gravity[4]
Lime (CaO): Limestone........................	0- 3	7.44	1.00	32	1.18
Lime, magnesia: Dolomite....................	0- 3	7.55	1.01	35	1.18
Alumina: Aluminum hydroxide.................	15	5.40	0.73	30	1.04
Light weight aggregate: Clay, shale.........	3- 7	2.54	0.34	18	0.56
Petroleum coke: Burn off volatiles..........	6-14	1.65	0.22	20	0.69
Clay: Evaporate H_2O and densifier...........	0-24	5.62	0.76	24	0.85
Periclase: Brucite, magnesiz................	50	12.68	1.70	30	1.93
Phosphate:					
Nodulize...................................	15-30	3.31	0.44	22	1.28
Calcine $CaCO_3$..............................	0- 1	4.32	0.58	36	1.28
Burn off carbonaceous material.............	10-15	2.04	0.27	20	1.28
Diatomaceous earth: Burn off car-					
bonaceous material..........................	0- 5	4.8	0.63	15	0.52
Manganese oxide: Manganese carbonate........	3-10	4.5	0.60	28	1.90

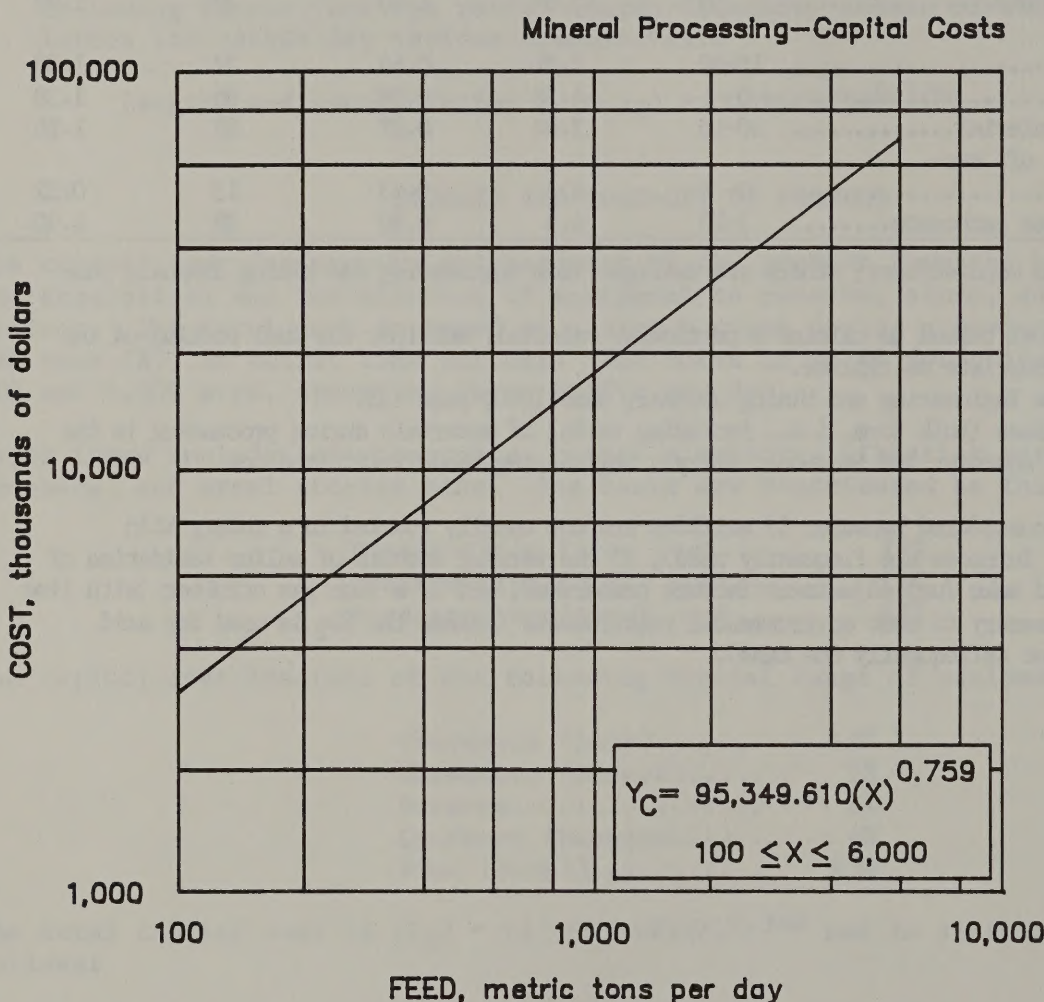
[1]Lime value is from kiln manufacturer; others are averages from Engineering and Mining Journal, June 1980, page 139.

[2]To determine cost of coal burned to calcine a particular material, multiply the fuel portion of the supplies curve by the appropriate multiplier.

[3]Averages for kiln: from Engineering and Mining Journal, June 1980, page 139.

[4]Approximate average values (bulk form, i.e., including voids) of materials during processing in the kiln; values from various sources: KVS Handbook, Perry's Engineering Manual, CRC Handbook.

NOTE.—No sulfides are considered because: 1) sulfides are not usually roasted in a rotary kiln (multiple-hearth vertical furnaces are frequently used), 2) the varying amounts of sulfur (oxidation of which is exothermic) would make fuel adjustment factors cumbersome, and 3) a flue gas scrubber (with lime addition) is probably necessary to meet environmental requirements (unless the SO_2 is used for acid manufacturing, which is not infrequently the case).



6.1.6.3. Calcination (rotary kiln)

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.4. CALCINING (DEAD-BURN MAGNESIUM)

The capital cost for calcining is for the acquisition and installation of equipment needed to process dead-burned dolomite. The calcining circuit consists of kilns, coolers, scrubbers, and related equipment such as conveyors.

BASE CURVE

The total cost is based on a single cost curve having a capacity rate (X), in metric tons of feed material to the kiln per day. The curve is valid for capacities between 60 and 910 mtpd, operating on a continuous basis. The curve includes all costs associated with the acquisition and installation of the calcining circuit.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	12.3%
Construction supply cost...	1.9%
Purchased equipment cost...	81.5%
Transportation cost........	4.3%

The total capital cost is $(Y_C) = 88{,}034.896(X)^{0.728}$ and is distributed as follows:

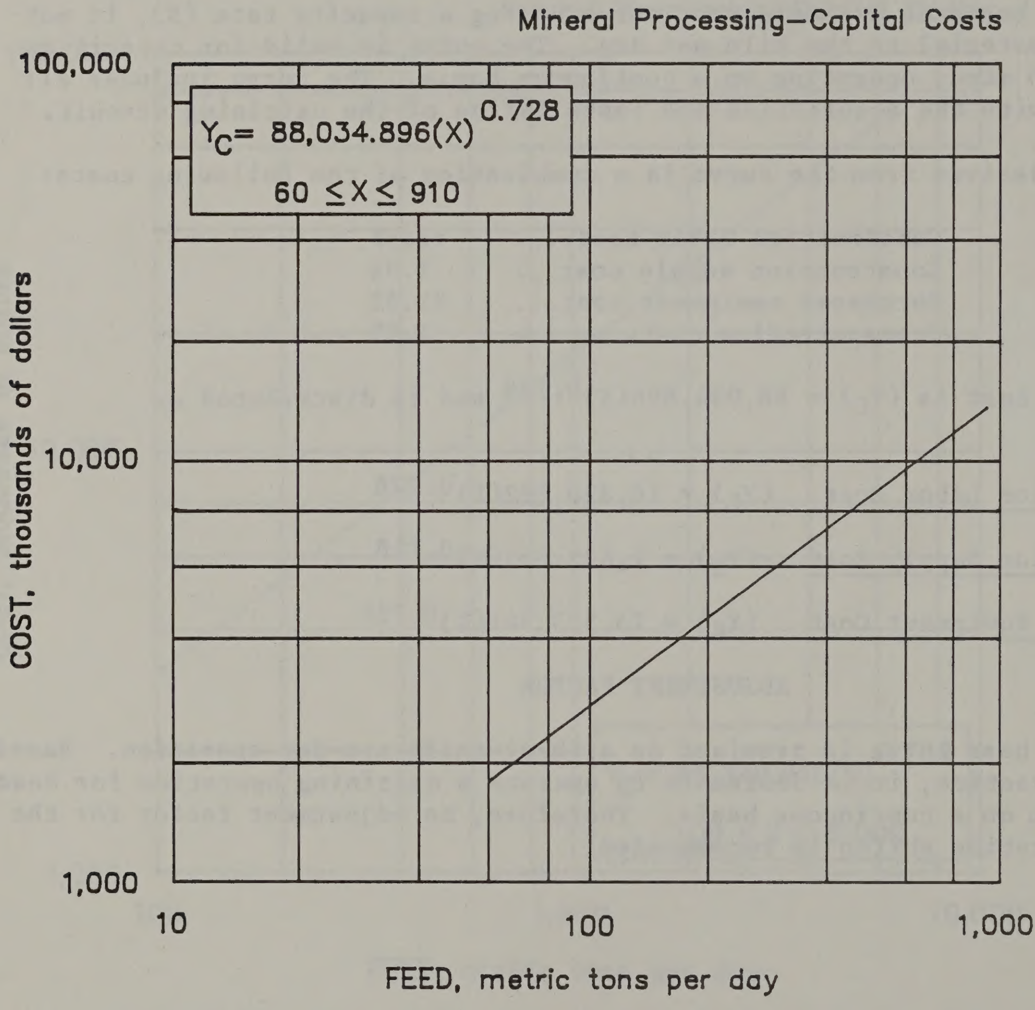
(L) Construction Labor Cost $(Y_L) = 10{,}828.292(X)^{0.728}$

(S) Construction Supply Cost $(Y_S) = 1{,}672.663(X)^{0.728}$

(E) Purchased Equipment Cost $(Y_E) = 75{,}533.941(X)^{0.728}$

ADJUSTMENT FACTOR

Shift Factor The base curve is premised on a three-shift-per-day operation. Based on industry practice, it is desirable to operate a calcining operation for dead-burn magnesium on a continuous basis. Therefore, no adjustment factor for the number of operating shifts is recommended.



6.1.6.4. Calcining (deadburned magnesium)

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.5. COMPACTION

The capital cost for compaction is for the acquisition and installation of equipment needed to compact potash crystals to a final product. The compaction circuit includes impactors, screw conveyors, belt conveyors, bucket elevators, screens, and impactors. The total capital cost is based on a single curve having an adjusted feed rate (X), in metric tons of final compacted product per day. The curve is valid for operations between 220 and 3,150 mtpd, operating three shifts per day.

BASE CURVE

The base curve is predicated on processing potash crystals to a final product. The base curve assumes that 50% of the compactor feed will report as final product. The remaining feed recycles back to the compactor as fines.

The total cost includes the costs associated with the acquisition and installation of the screw conveyors, compactors, screens and impactors.

The compaction capital cost derived from the curve is a combination of the following costs:

Installation labor cost......	3.0%
Installation materials cost..	4.6%
Purchased equipment cost.....	91.8%
Transportation cost..........	0.6%

The total compaction capital cost is $(Y_C) = 6{,}954.771(X)^{0.837}$ and is distributed as follows:

(L) <u>Installation Labor Cost</u> $(Y_L) = 208.643(X)^{0.837}$

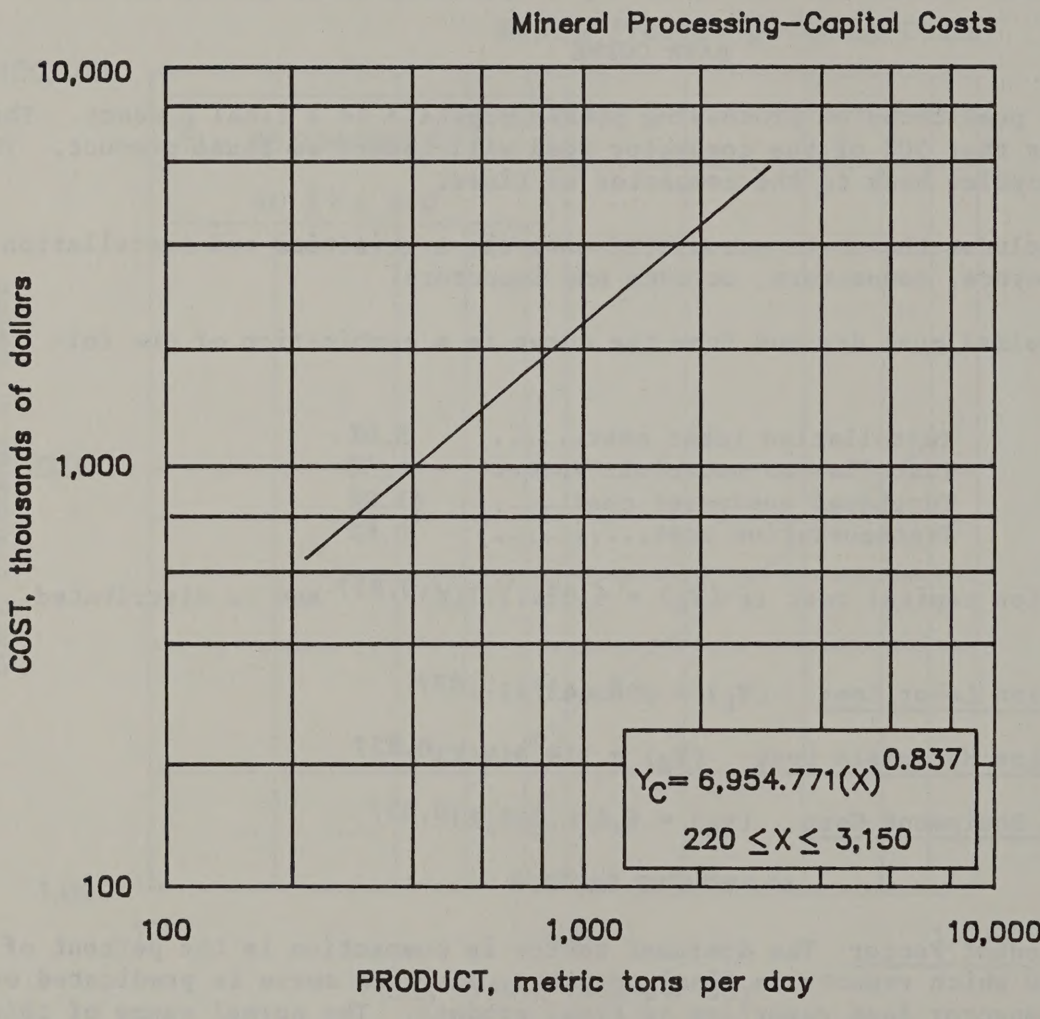
(S) <u>Installation Materials Cost</u> $(Y_S) = 319.919(X)^{0.837}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 6{,}426.208(X)^{0.837}$

ADJUSTMENT FACTORS

<u>Compactor Feed Product Factor</u> The dominant factor in compaction is the percent of compactor feed which reports as final product. The base curve is predicated on 50% of the compactor feed reporting as final product. The normal range of this vari- able is 25% to 75% of the feed reporting as product. To adjust for varying quan- tities of product in the compactor feed, multiply the cost obtained from the curve by the following factor:

Compactor feed product factor $(F_P) = 0.967[50/(P)]^{0.831}$
where P = feed reporting as product, in percent.



6.1.6.5. Compaction

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.6. CRYSTALLIZATION

The capital cost includes the acquisition and installation of equipment items associated with the crystallization circuit for potash. Major equipment items include dissolving (leaching) tanks, hot thickener, pumps, crystallizers, cyclones, heat exchangers, and centrifuges. The total capital cost for the potash crystallization circuit is based on a single curve having an adjusted feed rate (X), in metric tons of crystallized product per day. The curve is valid for operations between 50 and 4,350 mtpd, operating three shifts per day.

BASE CURVE

The curve includes all costs associated with the acquisition and installation of the purchased equipment items.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost....	2.6%
Construction supply cost...	17.8%
Purchased equipment cost...	78.5%
Transportation cost........	1.1%

The total capital cost is $(Y_C) = 56,341.633(X)^{0.655}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 1,464.882(X)^{0.655}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 10,028.811(X)^{0.655}$

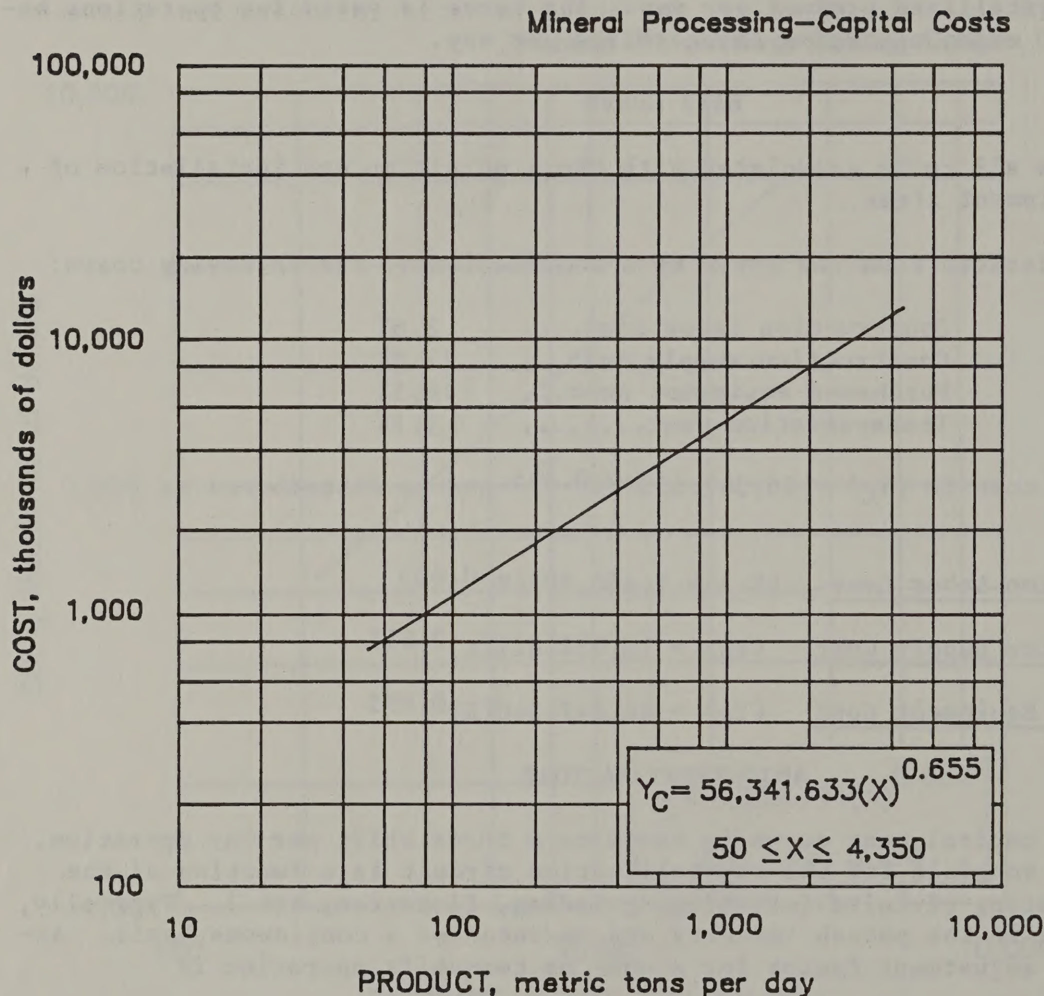
(E) <u>Purchased Equipment Cost</u> $(Y_E) = 44,847.940(X)^{0.655}$

ADJUSTMENT FACTORS

<u>Shift Factor</u> The capital cost curve is based on a three shift per day operation. The operating schedule for the crystallization circuit is a function of the previous operating circuits (crushing, grinding, flotation, etc.). Typically, these circuits in the potash industry are operated on a continuous basis. Accordingly, no adjustment factor for a one- or two-shift operation is recommended.

<u>Leaching Factor</u> The base curve is premised on feed sources from effluents, baghouses, and dust collectors to the crystallizer circuit for the recovery of crystallized potash. To adjust for the leaching of tailings or ore, multiply the cost obtained from the curve by the following factor:

Leaching factor $(F_L) = 1.46$



6.1.6.6. Crystallization

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.7. FRASCH PROCESS

The capital cost includes the acquisition and installation of equipment items associated with the Frasch process. Major equipment items include the sulfur wells, mine water heaters, hot process water softeners, air compressors, reagent handling system, sulfur relay stations, storage tanks, sulfur loading facilities, and pumps. The total capital cost is based on a single cost curve having an adjusted feed rate (X), in metric tons of sulfur per day. The curve is valid for operations between 1,150 and 7,900 mtpd, operating three shifts per day.

BASE CURVE

The total capital cost is based on a single curve at an adjusted feed rate (X) for the acquisition and installation of the purchased equipment items.

The Frasch process capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	25.6%
Construction supply cost.....	39.3%
Purchased equipment cost.....	34.7%
Transportation cost..........	0.4%

The total Frasch process capital cost is $(Y_C) = 24{,}851.517(X)^{0.991}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 6{,}361.988(X)^{0.991}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 9{,}766.646(X)^{0.991}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 8{,}722.882(X)^{0.991}$

ADJUSTMENT FACTOR

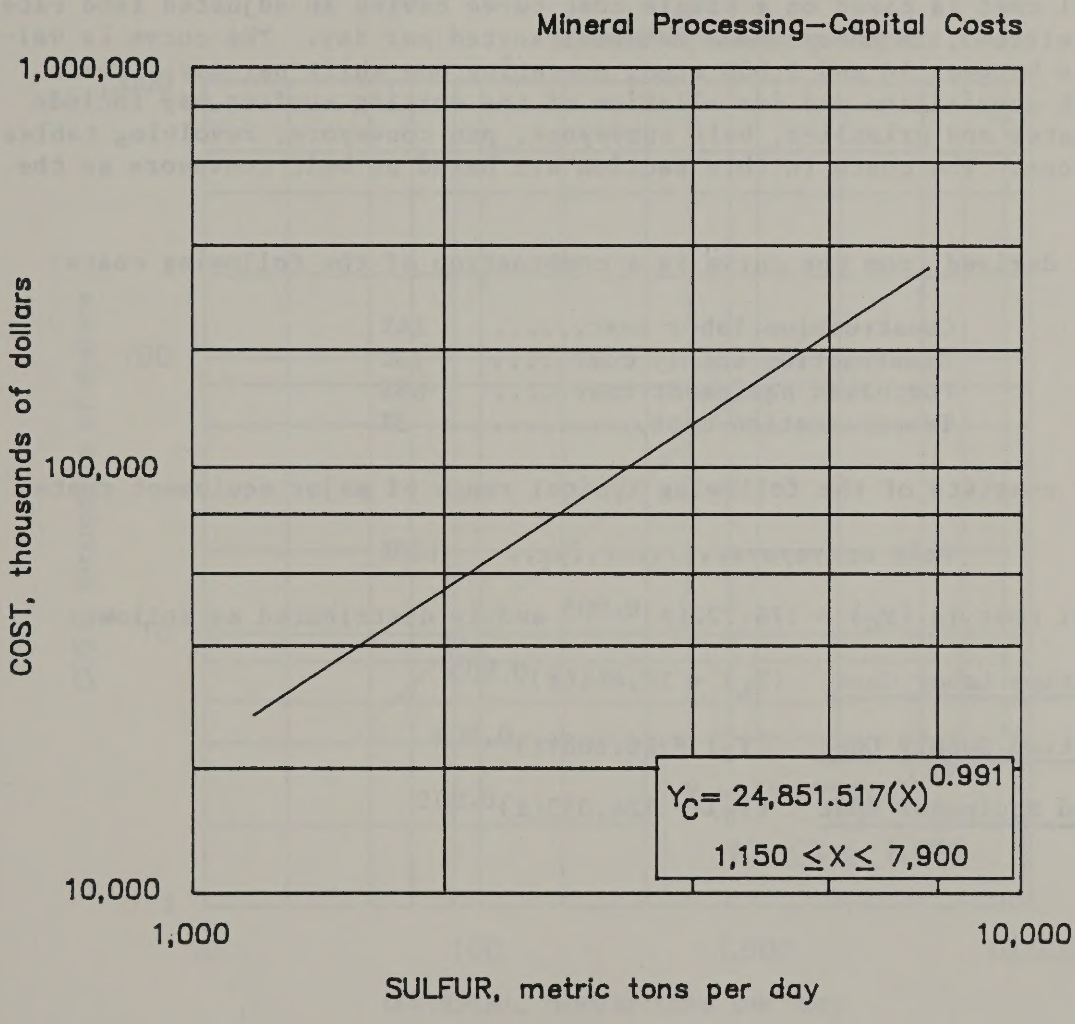
<u>Shift Factor</u> The base curve is based on a three-shift-per-day operation. Frasch process is typically operated on a continuous basis to maintain a steady production rate of molten sulfur. Therefore, no adjustment factor for a one or two-shift operation is recommended for Frasch processing.

<u>Water-Sulfur Ratio Factor</u> The base curve is based on a water-sulfur ratio of 3,000 gal of water per metric ton of sulfur produced. To adjust the base curve for other ratios, the multiply the cost obtained from the curve by the following factor:

Water-sulfur ratio factor $(F_R) = 0.00652(R)^{0.629}$
where R = water-sulfur ratio, in gallons of water per metric ton of sulfur produced, (to convert liters to gallons multiply liters by 0.2642).

Water Quality Factor The curve is based on a raw water quality as total hardness of 100 mg of $CaCO_3$ per milliliter. To adjust the base curve for other water qualities, the multiply the cost obtained from the curve by the following factor:

Water quality factor $(F_W) = 0.975(W)^{0.0056}$
where W = water quality as total hardness of $CaCO_3$, in milligrams per milliliter.



6.1.6.7. Frasch process

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.8. HANDSORTING

The handsorting capital cost is for acquisition and installation of auxiliary equipment for sorting ore by hand.

BASE CURVE

The total capital cost is based on a single cost curve having an adjusted feed rate to the picking belt (X), in metric tons material sorted per day. The curve is valid for operations between 40 and 2,000 mtpd, operating one shift per day. Costs as- sociated with acquisition and installation of the sorting surface may include tables, fixed chutes and grizzlies, belt conveyors, pan conveyors, revolving tables, or shaking surfaces. The costs in this section are based on belt conveyors as the sorting surface.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	14%
Construction supply cost.....	15%
Purchased equipment cost.....	68%
Transportation cost..........	3%

The capital cost consists of the following typical range of major equipment costs:

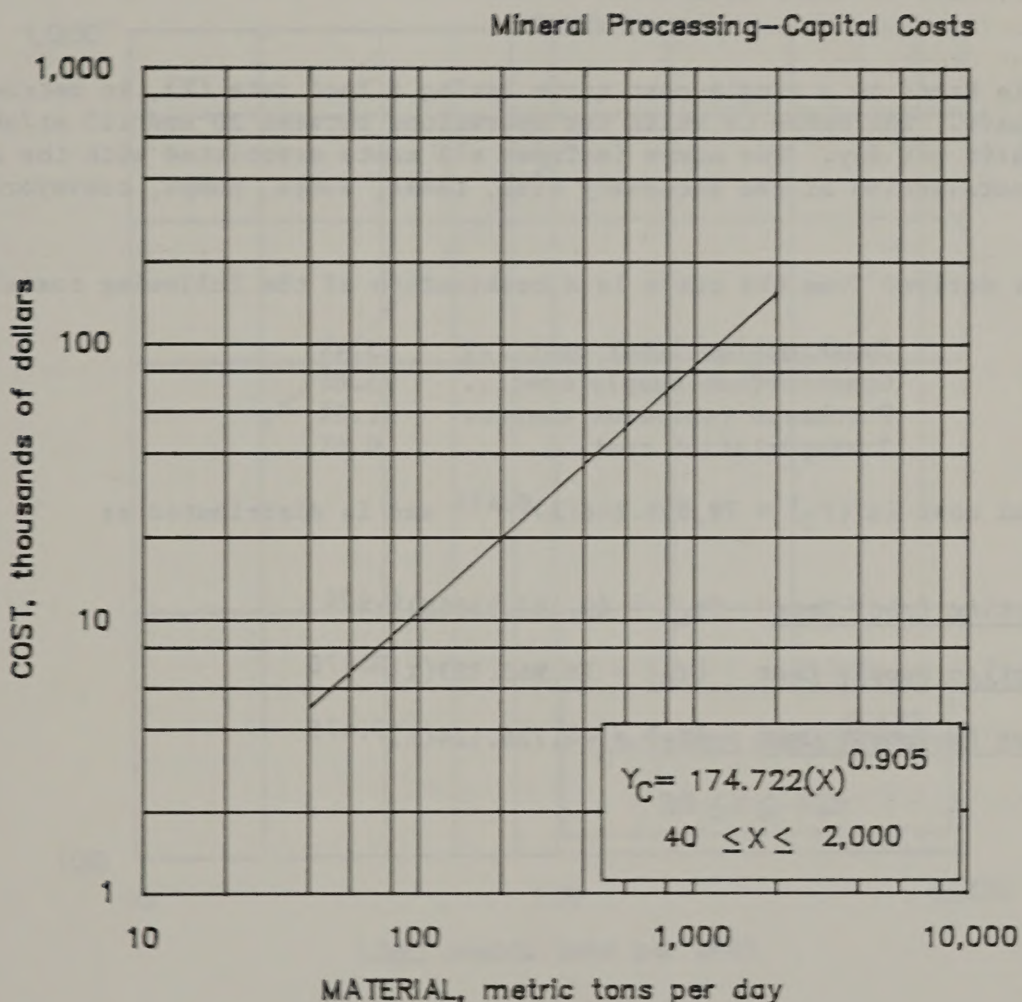
Belt conveyors..............	100%

The total capital cost is $(Y_C) = 174.722(X)^{0.905}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 24.461(X)^{0.905}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 26.208(X)^{0.905}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 124.053(X)^{0.905}$



6.1.6.8. Handsorting

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.9. LIME SLAKING

The capital cost for lime slaking is for the acquisition and installation of equipment needed to process pebble lime to a lime slurry. The lime slaking circuit includes dry storage, ball-mill slaking, cyclone classification, and slurry storage. The circuit can process pebble lime with a maximum size of 3 in delivered by bottom-dump truck.

BASE CURVE

The total cost is based on a single cost curve having a feed rate (X), in metric tons lime per shift. The curve is valid for operations between 20 and 125 mt/shift, operating one shift per day. The curve includes all costs associated with the acquisition and installation of the necessary bins, tanks, sumps, pumps, conveyors, and ball mill.

The capital cost derived from the curve is a combination of the following costs:

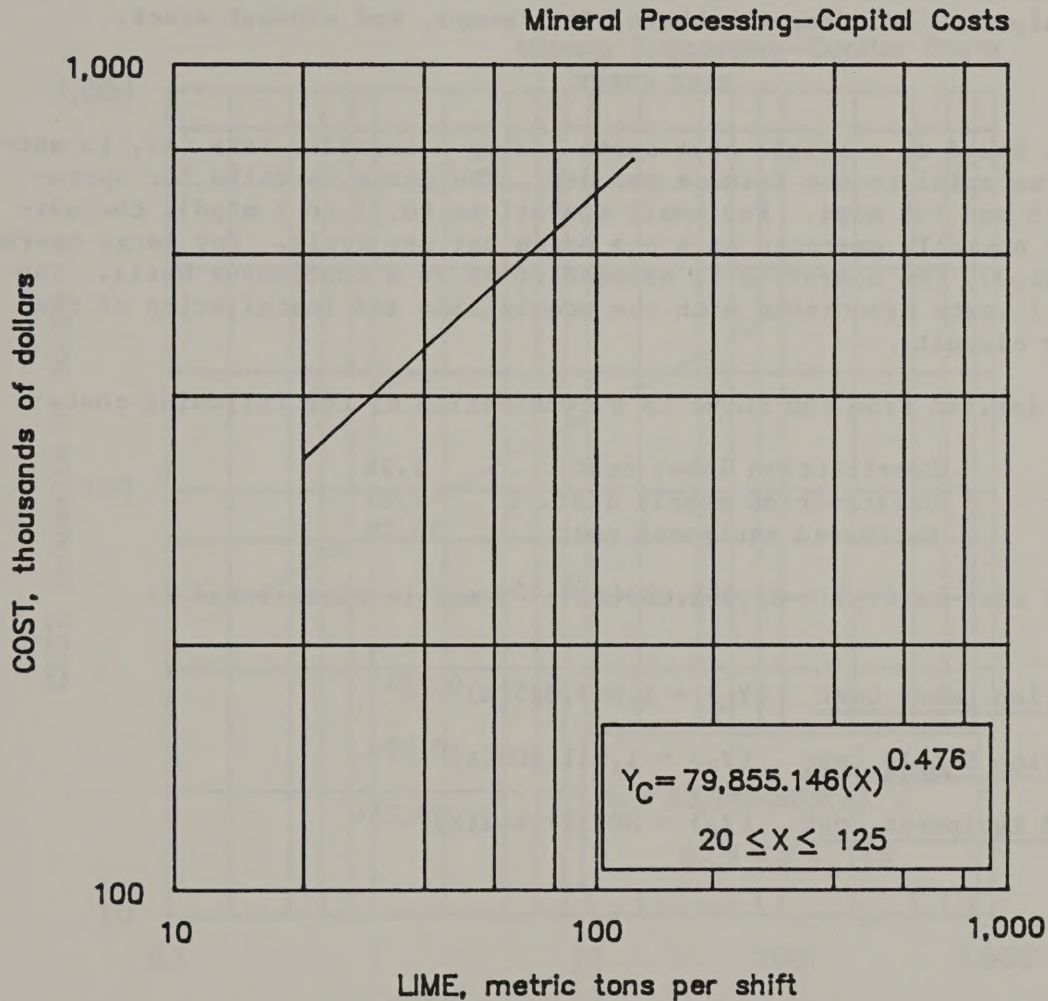
Construction labor cost....	23.4%
Construction supply cost...	25.0%
Purchased equipment cost...	51.0%
Transportation cost........	0.6%

The total capital cost is $(Y_C) = 79{,}855.146(X)^{0.476}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 19{,}165.235(X)^{0.476}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 19{,}963.787(X)^{0.476}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 40{,}726.124(X)^{0.476}$



6.1.6.9. Lime slaking

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.10.1. MERCURY APPLICATIONS
MERCURY CONDENSERS

The capital cost for mercury condensers is for the acquisition and installation of equipment needed to process furnace gases from primary mercury operations for the recovery of mercury or retort gases from gold-silver operations for the removal of mercury. The mercury condenser circuit consists of the condenser tubes or pipes and pollution equipment including scrubbers, fan, pumps, and exhaust stack.

BASE CURVE

The total cost is based on a single cost curve having a capacity rate (X), in metric tons of feed material to the furnace per day. The curve is valid for operations between 0.15 and 115 mtpd. For small operations (0.15 to 7 mtpd), the mercury condenser is normally operated on a one batch per day cycle. For large operations (7 to 115 mtpd), the operation is assumed to be on a continuous basis. The curve includes all costs associated with the acquisition and installation of the mercury condenser circuit.

The capital cost derived from the curve is a combination of the following costs:

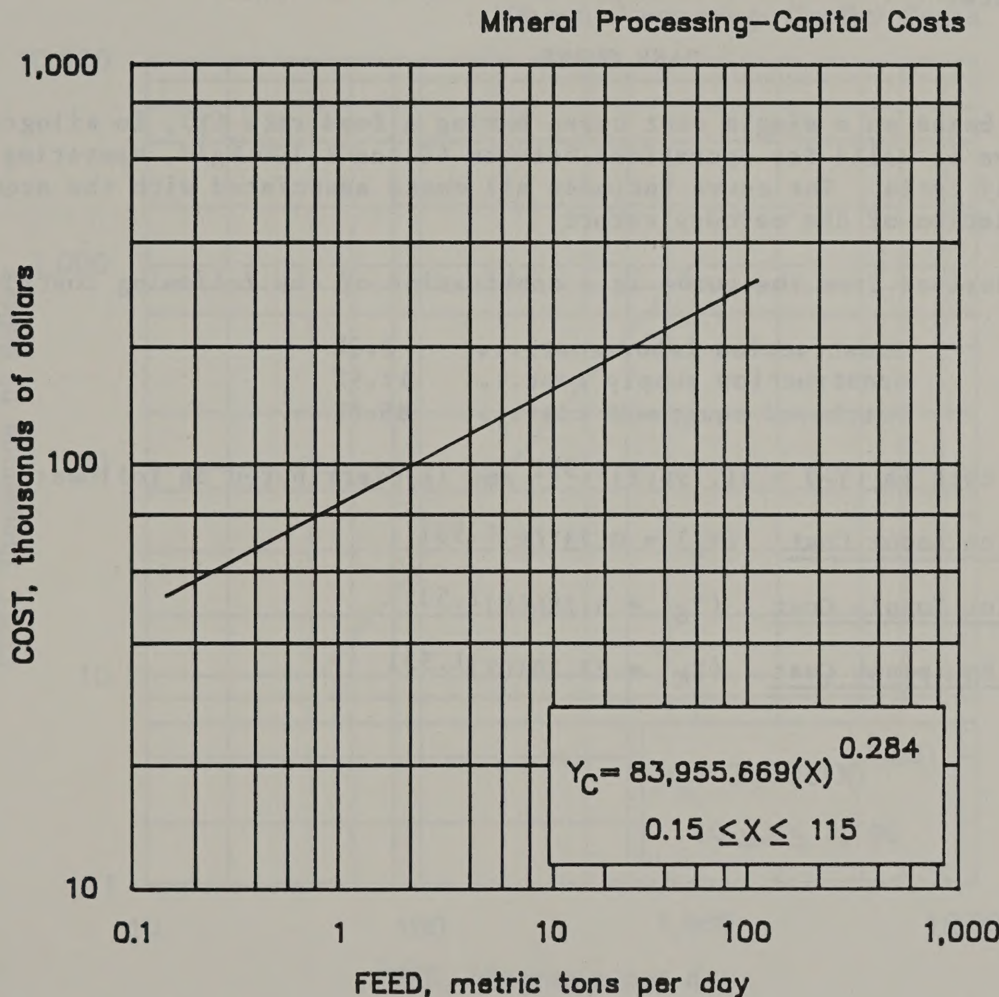
Construction labor cost....	2.2%
Construction supply cost...	1.8%
Purchased equipment cost...	96.0%

The total capital cost is $(Y_C) = 83{,}955.669(X)^{0.284}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 1{,}847.025(X)^{0.284}$

(S) Construction Supply Cost $(Y_S) = 1{,}511.202(X)^{0.284}$

(E) Purchased Equipment Cost $(Y_E) = 80{,}597.442(X)^{0.284}$



6.1.6.10.1. Mercury applications
MERCURY CONDENSERS

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.10.2. MERCURY APPLICATIONS
MERCURY RETORTS

The capital cost for mercury retorts is for acquisition and installation of equipment needed to process steel-wool cathodes or precipitates from gold-silver operations for the removal of mercury. The mercury retort circuit consists of the mercury retort furnace including the retort, furnace lining, boats, resistance heaters, and controllers.

BASE CURVE

The total cost is based on a single cost curve having a feed rate (X), in kilograms per day. The curve is valid for operations between 40 and 1,100 kg/d, operating on a one-batch-per-day cycle. The curve includes all costs associated with the acquisition and installation of the mercury retort.

The capital cost derived from the curve is a combination of the following costs:

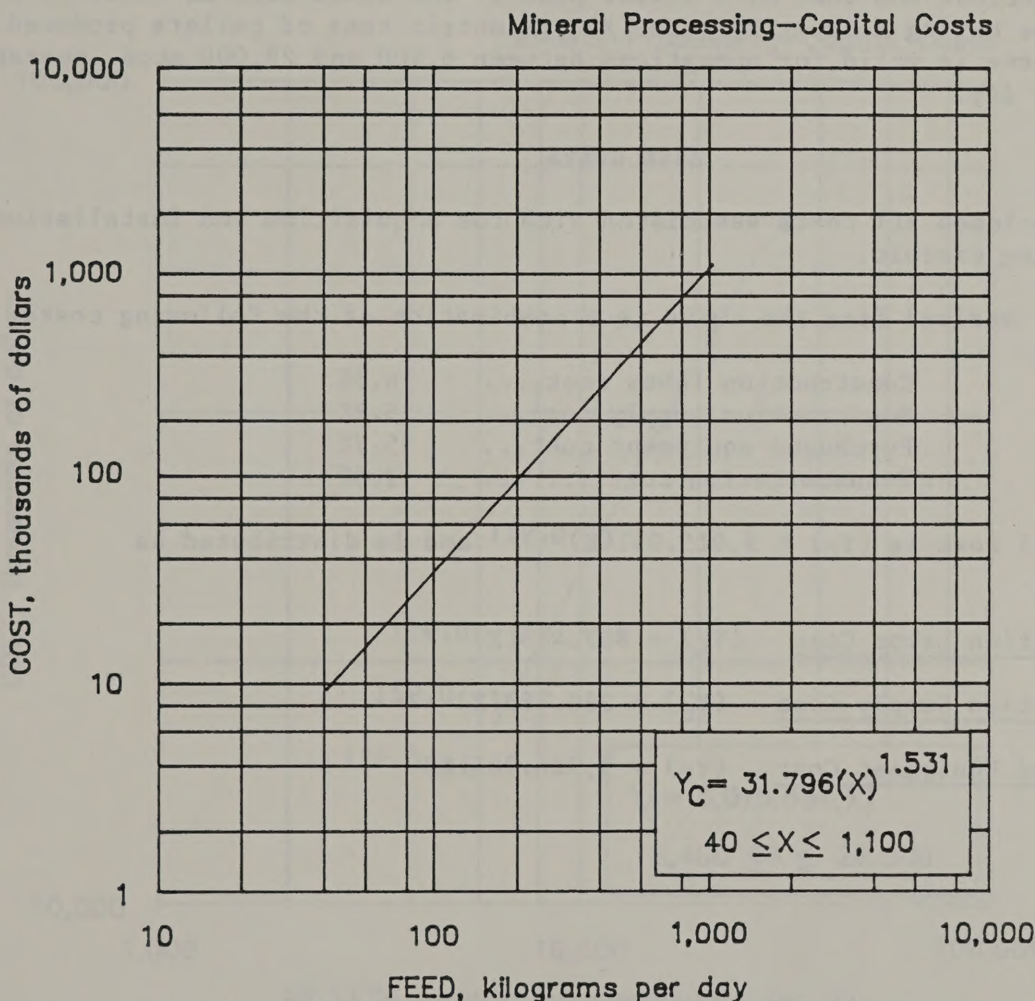
Construction labor cost....	2.3%
Construction supply cost...	11.9%
Purchased equipment cost...	85.8%

The total capital cost is $(Y_C) = 31.796(X)^{1.531}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 0.731(X)^{1.531}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 3.784(X)^{1.531}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 27.281(X)^{1.531}$



6.1.6.10.2. Mercury applications
MERCURY RETORTS

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.11. PELLETIZING

The capital cost for pelletizing is for the acquisition and installation of equipment needed to produce pellets from an iron ore concentrate. The pelletizing plant consists of balling drums, induration furnace, and related equipment such as conveyors, mixers, fans, and scrubbers. The base curve is predicated on the pelletizing treatment of an iron concentrate processed from magnetic ore. The pelletizing plant does not include the cost of a filter plant. The total cost is based on a single cost curve having a capacity rate (X), in metric tons of pellets produced per day. The curve is valid for operations between 6,400 and 28,000 mtpd, operating three shifts per day.

BASE CURVE

The base case includes all costs associated with the acquisition and installation of the pelletizing circuit.

The capital cost derived from the curve is a combination of the following costs:

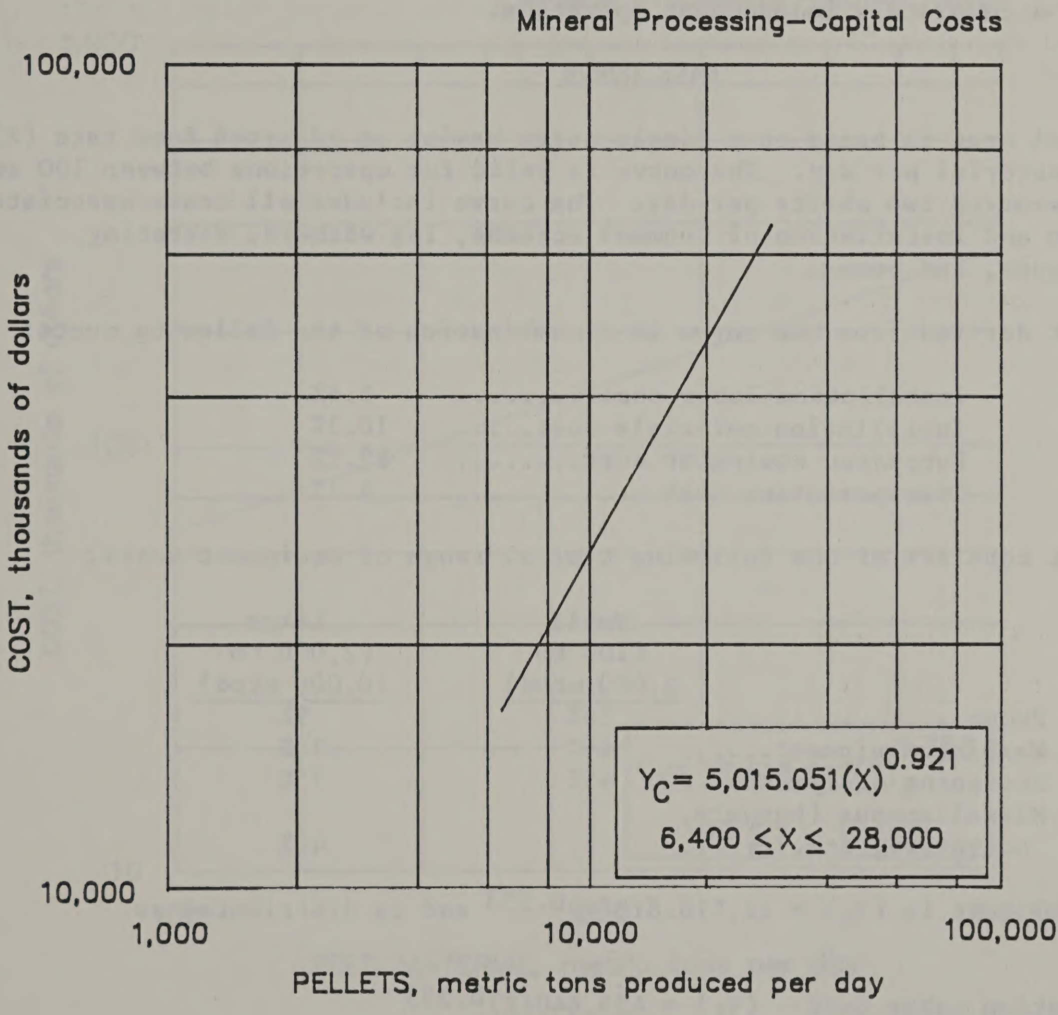
Construction labor cost....	16.5%
Construction supply cost...	5.2%
Purchased equipment cost...	75.7%
Transportation cost........	2.6%

The total capital cost is $(Y_C) = 5{,}015.051(X)^{0.921}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 827.483(X)^{0.921}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 260.783(X)^{0.921}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 3{,}926.785(X)^{0.921}$



6.1.6.11. Pelletizing

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.12.1. WASHING AND SCREENING

The washing and screening capital cost is for acquisition and installation of equipment to wash and screen loosely consolidated ores such as barite. Washing separates the gangue from the ore and screening separates the ore into two or more sizes. The sized ore is then usually processed further by various means. Washing is usually the first step as the ore enters the processing plant. Screening may be combined with crushing and grinding in various combinations depending on plant design, or may be a completely independent operation.

BASE CURVE

The total capital cost is based on a single curve having an adjusted feed rate (X), in metric tons material per day. The curve is valid for operations between 100 and 10,000 mtpd, operating two shifts per day. The curve includes all costs associated with acquisition and installation of trommel screens, log washers, vibrating screens, water guns, and pumps.

The capital cost derived from the curve is a combination of the following costs:

Installation labor cost.........	3.4%
Installation materials cost.....	10.3%
Purchased equipment cost........	82.2%
Transportation cost.............	4.1%

The capital cost consists of the following typical range of equipment costs:

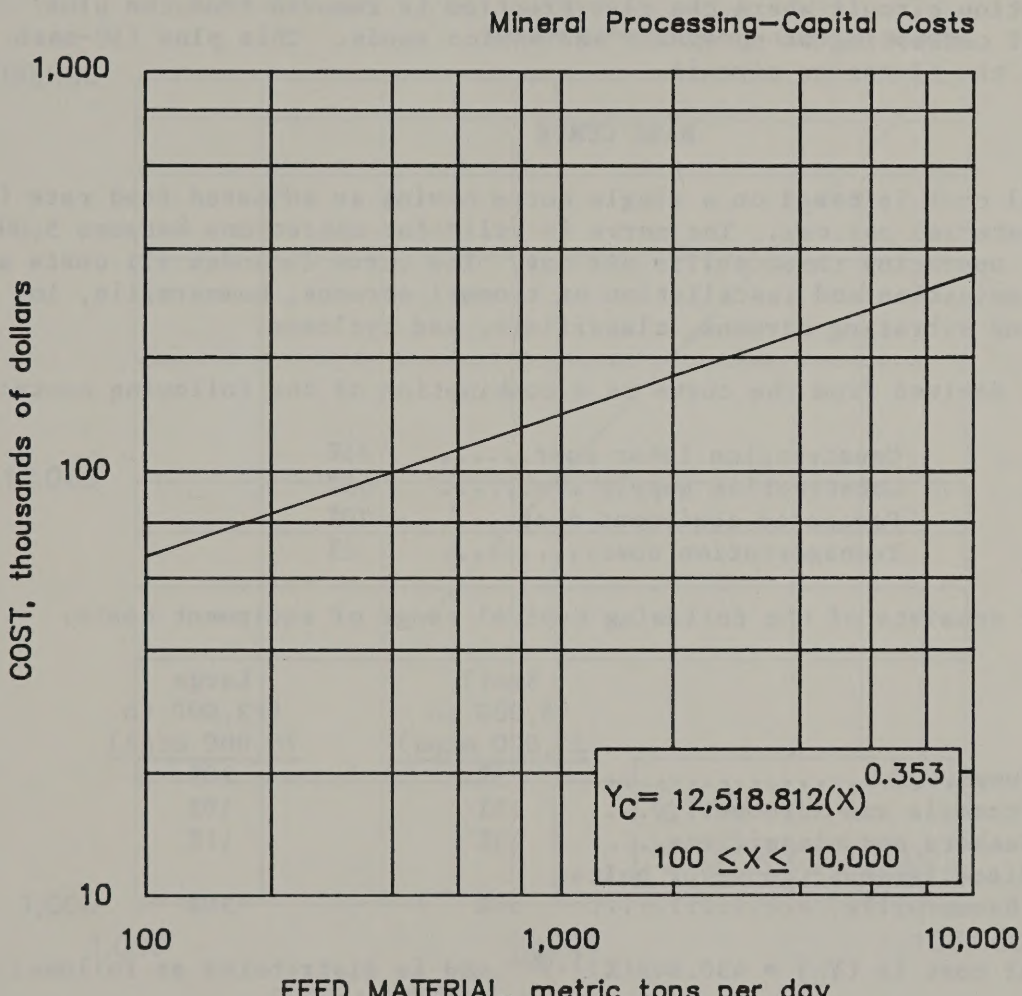
	Small (100 to 2,000 mtpd)	Large (2,000 to 10,000 mtpd)
Pumps.................	10%	9%
Washing equipment......	45%	10%
Screening equipment....	45%	35%
Miscellaneous (hoppers, conveyors, etc.)......	-	46%

The total capital cost is $(Y_C) = 12{,}518.812(X)^{0.353}$ and is distributed as follows:

(L) <u>Installation Labor Cost</u> $(Y_L) = 425.640(X)^{0.353}$

(S) <u>Installation Materials Cost</u> $(Y_S) = 1{,}289.438(X)^{0.353}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 10{,}803.735(X)^{0.353}$



6.1.6.12.1. Washing and screening

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.6. SPECIAL APPLICATIONS

6.1.6.12.2. WASHING AND SCREENING--PHOSPHATE

The washing and screening capital cost is for acquisition and installation of equipment to wash and screen (including ore feed preparation for flotation) of loosely consolidated phosphate ores. Washing and screening separates the minus 1.91-cm (0.75-in), plus 14- or 16-mesh phosphate material (called pebble concentrate) from the finer material. The finer material containing phosphate is then processed in the feed preparation circuit where the clay fraction is removed from the plus 150-mesh material consisting of phosphate and silica sands. This plus 150-mesh material goes to the flotation circuit.

BASE CURVE

The total capital cost is based on a single curve having an adjusted feed rate (X), in metric tons material per day. The curve is valid for operations between 5,000 and 70,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition and installation of trommel screens, hammermills, log washers, flume and vibrating screens, classifiers, and cyclones.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	35%
Construction supply cost.....	43%
Purchased equipment cost.....	20%
Transportation cost..........	2%

The capital cost consists of the following typical range of equipment costs.

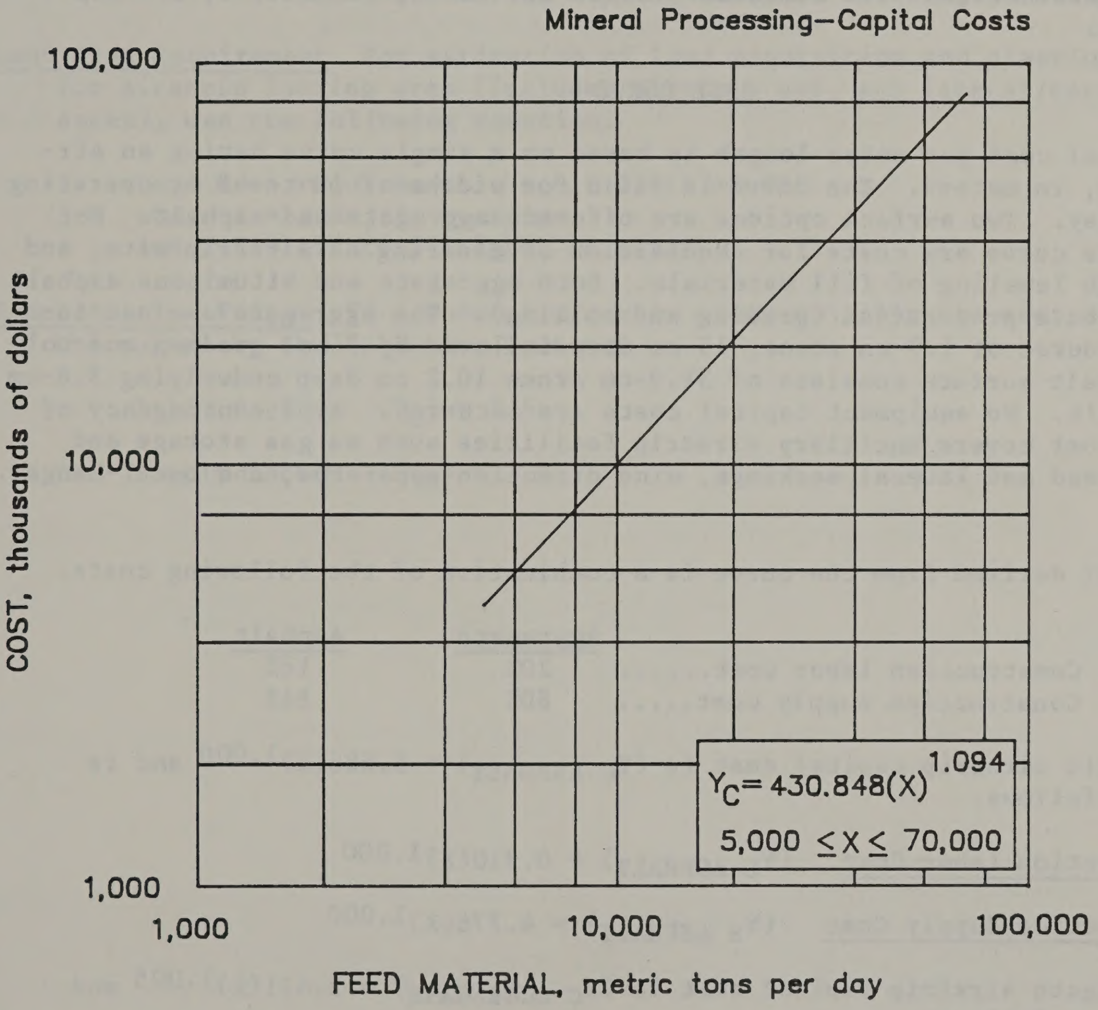
	Small (5,000 to 22,000 mtpd)	Large (22,000 to 70,000 mtpd)
Pumps......................	5%	20%
Trommels and screens........	15%	19%
Washers and classifiers.....	43%	11%
Miscellaneous (conveyor belts, hammermills, etc.).........	37%	50%

The total capital cost is $(Y_C) = 430.848(X)^{1.094}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 150.797(X)^{1.094}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 185.265(X)^{1.094}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 94.786(X)^{1.094}$



6.1.6.12.2. Washing and screening
PHOSPHATE

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.7. TRANSPORTATION

6.1.7.2. AIRSTRIP CONSTRUCTION

Airstrip construction cost curves give the cost per meter length of basic utility airstrips varying in width from 10 to 40 m. The airstrip described accommodates light single-engine and small twin-engine airplanes used for personal and business purposes, plus a broader spectrum of small business and air taxi-type twin-engine airplanes. These aircraft include the Cessna 150 series, Piper PA-32-300 Commander Six, Rockwell International 114 Commander, Beech B55 Baron, Cessna 310, and Piper PA-23-250 Aztec.

BASE CURVE

The total capital cost per meter length is based on a single curve having an airstrip width (X), in meters. The curve is valid for widths of 10 to 40 m, operating one shift per day. Two surface options are offered, aggregate and asphalt. Not included in this curve are costs for acquisition or clearing of airstrip site, and hauling or rough leveling of fill materials. Both aggregate and bituminous asphalt strips include base preparation (grading and rolling). The aggregate surface includes a base course of 1.9-cm stone, 15 cm deep followed by final grading and rolling. The asphalt surface consists of 31.9-cm stone 10.2 cm deep underlying 3.8-cm of rolled asphalt. No equipment capital costs are incurred. A 5% contingency of total capital cost covers ancillary airstrip facilities such as gas storage and pump, airstrip end and lateral markings, wind direction apparatus, and one T-hangar as needed.

The capital cost derived from the curve is a combination of the following costs:

	Aggregate	Asphalt
Construction labor cost......	20%	16%
Construction supply cost.....	80%	84%

The total asphalt airstrip capital cost is $(Y_{C\ ASPHALT}) = 5.686(X)^{1.000}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ ASPHALT}) = 0.910(X)^{1.000}$

(S) Construction Supply Cost $(Y_{S\ ASPHALT}) = 4.776(X)^{1.000}$

The total aggregate airstrip capital cost is $(Y_{C\ AGGREGATE}) = 3.471(X)^{1.005}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ AGGREGATE}) = 0.694(X)^{1.005}$

(S) Construction Supply Cost $(Y_{S\ AGGREGATE}) = 2.776(X)^{1.005}$

ADJUSTMENT FACTORS

Runway Length Runway length requirement is primarily dependent on anticipated aircraft use, temperature, and elevation. Aircraft type used in the cost curve was

previously described. For convenience, an equation was derived to determine length requirement when the elevation of the airstrip is known. The equation is based on maximum temperature of 38C (100F). To determine different lengths at different elevations, use the following equation:

Runway length $L = 891.915e^{(0.0005277)(E)}$
where L = length of airstrip, in meters,
and E = elevation, in meters.

Runway Width Runway width requirement varies with wingspan of anticipated aircraft using the airstrip. An 18-m wide landing strip will accommodate the aircraft mentioned. This width is advised for airstrip predesign costing. Actual width should be used when calculating capital costs of existing airstrips.

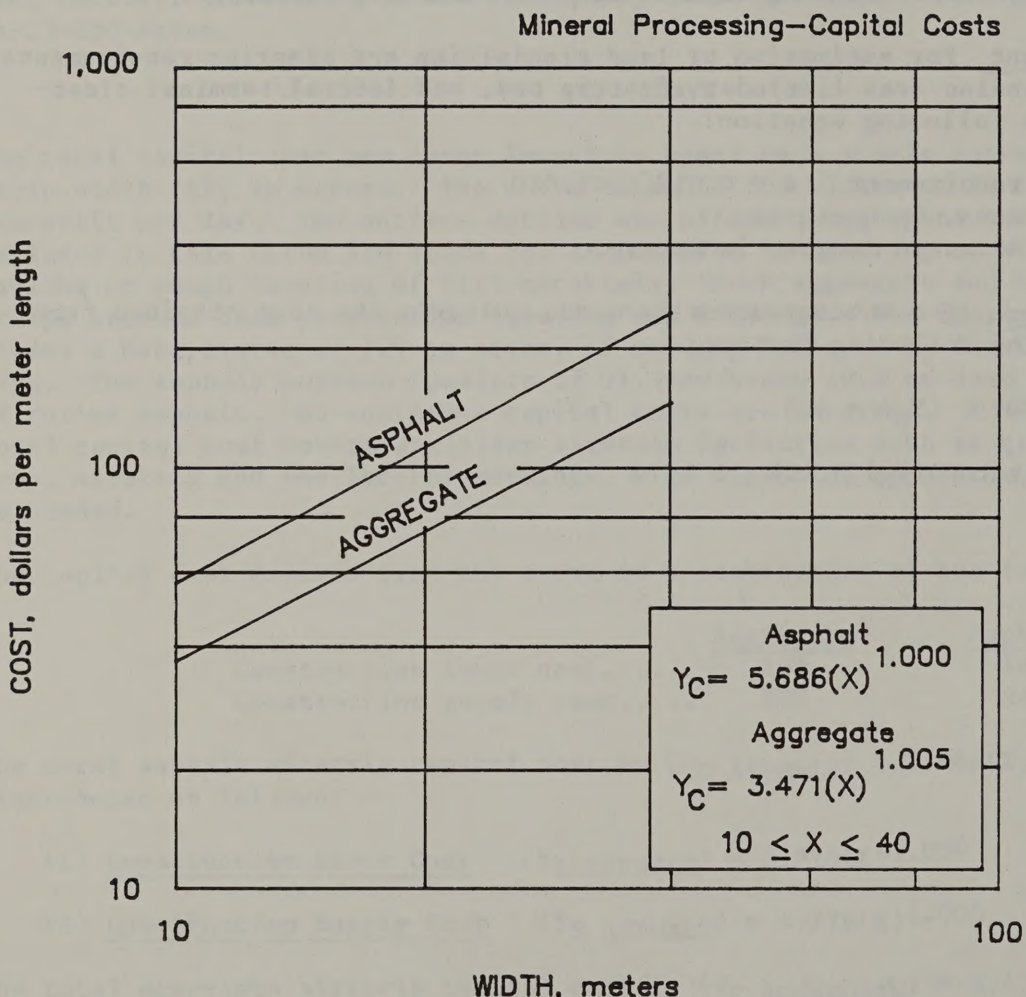
Land Area Requirement For estimation of land acquisition and clearing requirements for airstrip landing area (includes airstrip pad, and lateral/terminal clearances), use the following equation:

Land area requirement $A = 0.012(L)+1.820$
where A = area, in hectares,
and L = airstrip length, in meters.

Subcontractor Factor If a subcontractor is used, multiply the cost obtained from the curves by the following factors:

Labor factor $(Y_L) = 1.5$

Supply factor $(Y_S) = 1.2$



6.1.7.2. Airstrip construction

6.1.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.7. TRANSPORTATION

6.1.7.4. RAILROAD CONSTRUCTION

The cost in this section covers the capital expense for laying standard-gage trackage for main lines and spurs. The cost reflects railway installation by a crew that works on a one-shift-per-day schedule; furthermore, the cost is based on trackage that is fully ballasted.

BASE CURVE

The total capital cost is based on a single curve having a railroad length (X), in total kilometers. The curve is valid for a lengths of 1 to 60 km, operating one shift per day.

The final cost derived from the curve is a combination of the following costs:

Construction labor cost......	26%
Construction supply cost.....	69%
Purchased equipment cost.....	5%

The total railroad construction capital cost is $(Y_C) = 188{,}530.000(X)^{1.000}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 49{,}017.800(X)^{1.000}$

(S) Construction Supply Cost $(Y_S) = 130{,}085.700(X)^{1.000}$

(E) Purchased Equipment Cost $(Y_E) = 9{,}426.500(X)^{1.000}$

ADJUSTMENT FACTORS

Ballast Factor For the installation of standard-gage trackage without ballast, multiply the cost obtained from the curve by the following factor:

Ballast factor $(F_B) = 0.85$

Roadbed Construction For construction expenses resulting from roadbed clearing, drilling/blasting, and excavation, refer to Access Roads sections (6.1.10.1.1.-6.1.10.1.3.) and apply a roadway width of 6.1 m to the applicable cost equations; the additional railway expenses so derived should then be added to this section's capital cost.

Equipment Factor When it is necessary to purchase equipment or to have a subcontractor perform the work, multiply the equipment operation value by the following factor in order to obtain the total value of equipment expense for ownership and operation:

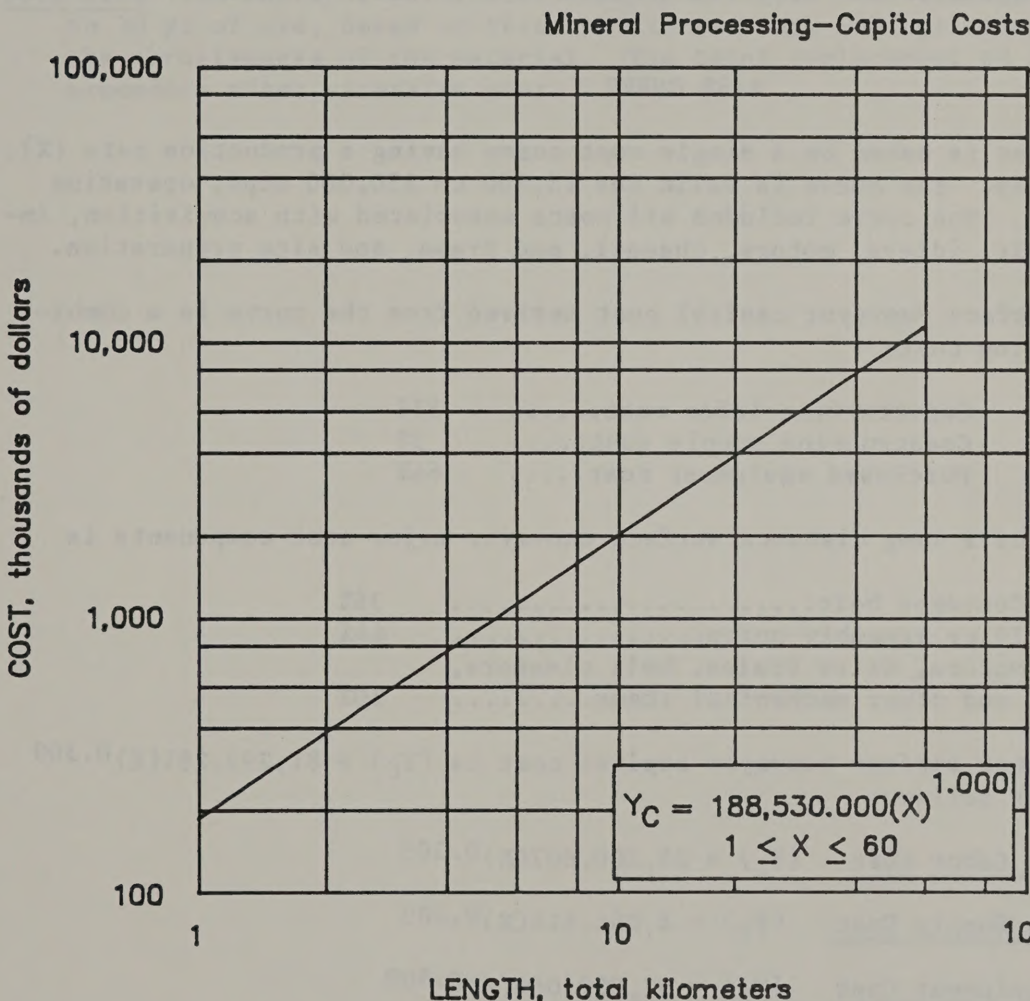
Equipment factor $(Y_E) = 1.7$

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor $(Y_L) = 1.5$

Supply factor $(Y_S) = 1.2$

Equipment operation factor $(Y_E) = 1.2$



6.1.7.4. Railroad construction

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.7. TRANSPORTATION

6.1.7.5. LONG-DISTANCE SURFACE CONVEYOR

The cost curve shown is for the acquisition and erection of a long-distance surface conveyor. The conveyor is a single-flight belt conveyor made with high-strength steel belting. The conveyor is designed for a 10° slope and 1-km distance. Usually, the material is crushed or screened at the mine site before being conveyed. Screen and crusher capital costs are not included in this cost but are covered in separate sections.

BASE CURVE

The total capital cost is based on a single cost curve having a production rate (X), in metric tons per day. The curve is valid for 15,000 to 150,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition, installation of the belt, idlers, motors, channel, and frame, and site preparation.

The long distance surface conveyor capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	31%
Construction supply cost.....	5%
Purchased equipment cost.....	64%

A typical breakdown of a long distance surface conveyor major cost components is

Conveyor belt......................	36%
Idler assembly units................	44%
Motors, drive trains, belt cleaners, and other mechanical items.........	20%

The total long distance surface conveyor capital cost is $(Y_C) = 81{,}292.281(X)^{0.309}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 25{,}200.607(X)^{0.309}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 4{,}064.614(X)^{0.309}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 52{,}027.060(X)^{0.309}$

ADJUSTMENT FACTORS

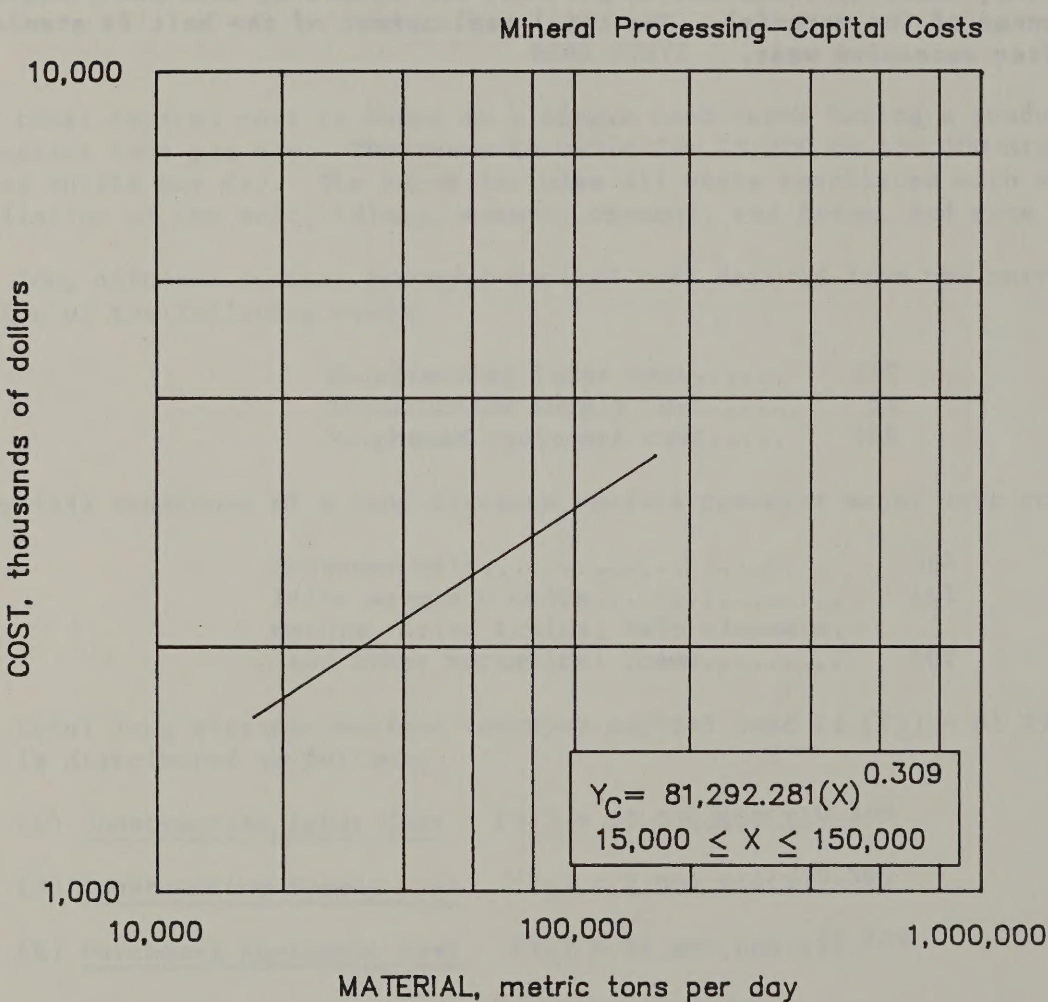
<u>Conveyor Length and Slope Factor</u> The conveyor is 1-km long and has a 10° slope. For other lengths and slopes, multilpy the cost obtained from the base curve by the following factor:

Conveyor length and slope factor $(F_L) = [0.917+0.00940(S)][L/1]$
where L = length, in kilometers,
and S = slope in degrees, between 0° and 15°.

The cost for a decline conveyor is equal to that for a horizontal conveyor (0° slope).

Stacker-Tripper Factor If the material is conveyed to a processing plant or other end point such as a port facility, the capital cost for unloading from the conveyor is included in those sections. If the material is waste rock, then the cost for a tripper or stacker should be added to the estimated capital cost. Costs for these items vary greatly but can range from $600,000 for a stacker or tripper that handles 15,000 mtpd waste material to $5,000,000 for a stacker or tripper that handles 150,000 mtpd of waste rock.

Belt Life The conveyor belt, 36% of equipment cost, has an average wear life of 8 to 10 yr of use, based on three shifts per day, 350 operating days per year, and the abrasiveness of the material. The total replacement of the belt is standard procedure after excessive wear.



6.1.7.5. Long distance surface conveyor

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.7. TRANSPORTATION

6.1.7.7. MARINE TERMINAL

The curve applies to costs for a deep-water, export bulk ore marine terminal. Costs include basic operations of rail or barge receiving, storage (open), reclaiming, and shiploading. Ore storage, with capability to mix different ore grades, has a capacity of 10% of annual throughput. It is assumed that soil conditions are good. Significant additional costs will be incurred under conditions of poor site soil (e.g., swamps, etc.) and shallow water (dredging required). Additionally, a requirement for covered storage will significantly add to capital costs. Capital costs do not include land acquisition, legal and permitting fees, finance charges, off-site alterations, and engineering and construction management fees (the latter, typically 8% of total direct costs).

BASE CURVE

The total capital cost is based on a single curve having a capacity (X), in metric tons of material per year. The curve is valid for capacities between 900,000 and 16,000,000 mt/yr, operating three shifts per day.

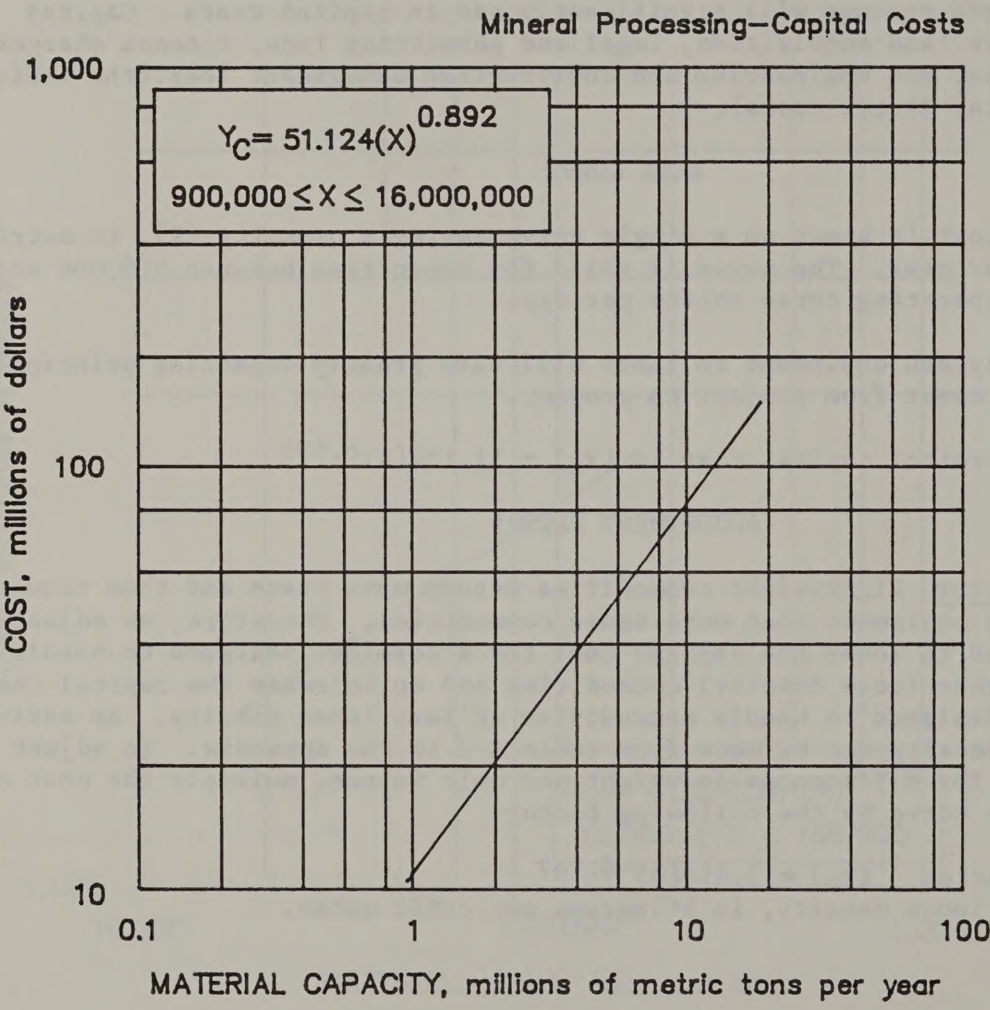
The ratios of supply and equipment to labor will vary greatly depending principally on the civil requirement from project to project.

The total marine terminal capital cost is $(Y_C) = 51.124(X)^{0.892}$

ADJUSTMENT FACTOR

<u>Density (Loose) Factor</u> Lightweight commodities occupy more space and thus require larger handling equipment than more dense commodities. Therefore, an adjustment is required to lower the capital cost for a terminal designed to handle more dense (higher loose density) commodities and to increase the capital cost of a terminal designed to handle commodities of less loose density. An estimate of loose density can be made from table A-2 in the appendix. To adjust the base curve for differences in weight per unit volume, multiply the cost obtained from the curve by the following factor:

Density factor $(Y_D) = 3.418(D)^{-0.167}$
where D = loose density, in kilograms per cubic meter.



6.1.7.7. Marine terminal

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.7. TRANSPORTATION

6.1.7.8. SLURRY PIPELINE

The capital cost curve for the slurry pipeline is for the acquisition and installation of equipment for pumping a slurry 10 km at a lift of 150 m with a specific gravity of the solids of 4.3. The slurry pipeline circuit includes slurry storage tanks, booster and high-pressure slurry pumps, and the pipeline.

The total capital cost is based on a single curve having an adjusted feed rate (X), in metric tons material slurried per day. The curve is valid for 900 to 32,000 mt/d, operating three shifts per day. The curve includes all costs associated with the acquisition and installation of the required pumps, agitators, slurry tanks, and pipeline.

BASE CURVE

The slurry pipeline capital cost derived from the curve is a combination of the following costs:

Installation labor cost......	11.8%
Installation materials cost..	32.9%
Purchased equipment cost.....	54.6%
Transportation cost..........	0.7%

The total slurry pipeline capital cost is $(Y_C) = 21{,}021.709(X)^{0.546}$ and is distributed as follows:

(L) Installation Labor Cost $(Y_L) = 2{,}480.562(X)^{0.546}$

(S) Installation Materials Cost $(Y_S) = 6{,}916.142(X)^{0.546}$

(E) Purchased Equipment Cost $(Y_E) = 11{,}625.005(X)^{0.546}$

ADJUSTMENT FACTORS

Pipeline Length Factor The curve is based on a slurry pipeline of 10 km in length. To adjust the base curve for different pipeline lengths, multiply the cost obtained from the curve by the following factor:

Pipeline length factor $(F_P) = 0.026(K)+0.741$
where K = length, in kilometers.

An estimate of average pipeline length can be made from table A-3 in the appendix.

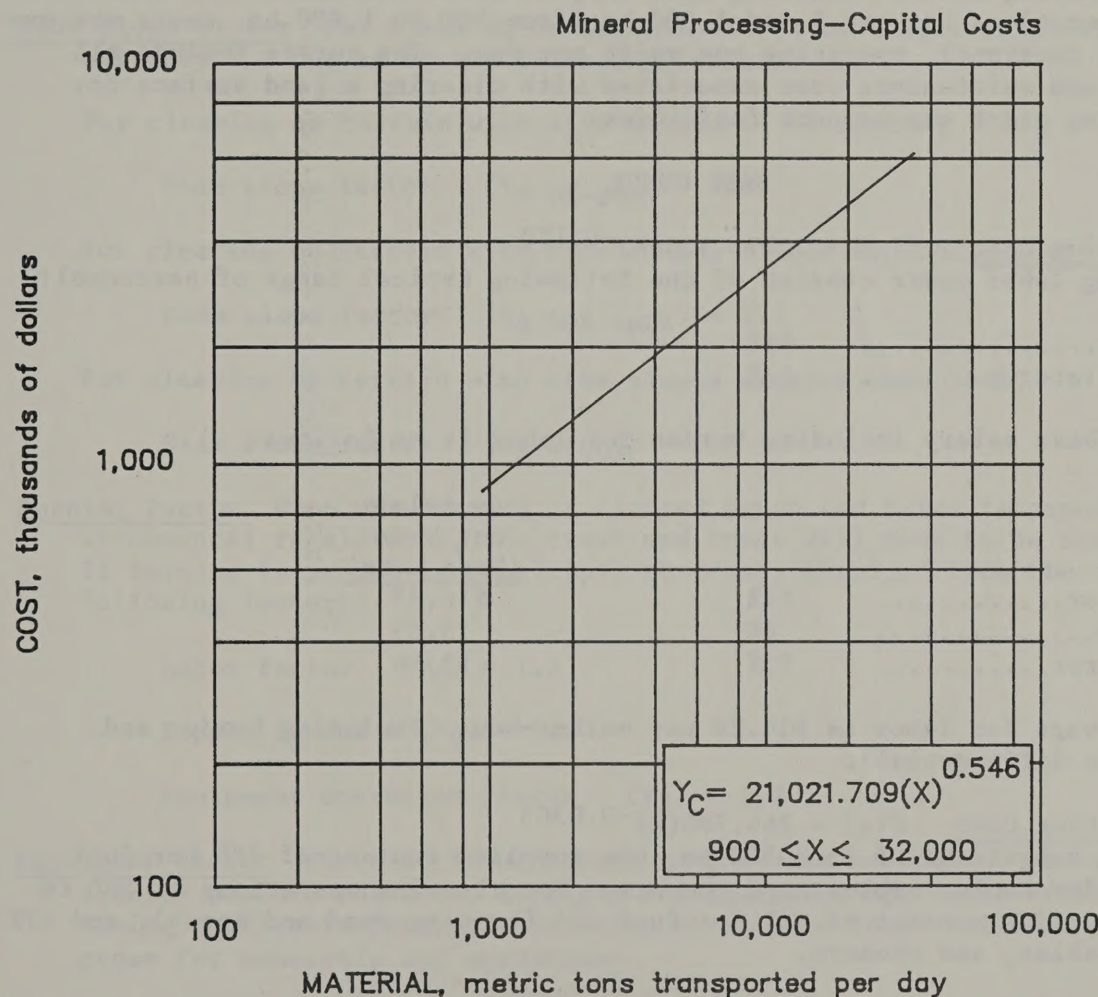
Slurry Pipeline Lift Factor The base curve was calculated for a slurry pipeline with a lift of 150 m. To adjust the base curve for a different lift, multiply the cost obtained from the curve by the following factor:

Lift factor $(F_L) = 0.0009(L)+0.871$
where L = length, in meters.

<u>Specific Gravity Factor</u> The base curve was calculated for a slurry pipeline pumping solids with specific gravity of 4.3. To adjust the curve for a different specific gravity, multiply the cost obtained from the curve by the following factor:

Specific gravity factor $(F_S) = 0.023(S)+0.903$
where S = new specific gravity.

An estimate of average specific gravity can be made from table A-3 in the appendix.



6.1.7.8. Slurry pipeline

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.1. CLEARING

The curve for clearing during site preparation is based on estimated costs for medium-light growth on terrain with a side slope of 20 to 50%, one shift per day. Estimate one tree, 0.33 m in diameter, per 40 m^2.

The total cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a total clearing area (X), in total hectares. The curves are valid for operations between 1 and 1,000 ha (from 500 to 1,000 ha, costs are expected to remain constant), operating one shift per day. The curves include all daily operating and maintenance cost associated with clearing a land surface for mineral processing plant and support facilities.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 2{,}171.220(X)^{-0.120}$

The operating labor costs consist of the following typical range of personnel:

Direct labor...............	86%
Maintenance labor..........	14%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Dozer operator............	21%	$16.33
Truck driver..............	6%	15.89
General laborer...........	73%	13.66

The average wage for labor is $14.28 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 269.796(X)^{-0.0303}$

For clearing operations of 1 to 500 ha, the supplies consist of 78% for fuel oil and 22% for tools, cables, and chokers. For clearing operations of 500 to 1,000 ha, supplies consist of 83% for fuel oil (burning wood and scrub), and 17% for tools, cables, and chokers.

(E) Equipment Operating Cost $(Y_E) = 667.618(X)^{-0.0672}$

Equipment operating costs consists of 87% for crawler dozers and 13% for trucks, pickups, and chainsaws.

The general equipment cost component distribution is as follows:

Description	Repair parts	Fuel and lube	Tires
Crawler dozers.............	51.0%	49.0%	-
Trucks, pickups, and chainsaws.............	14.0%	80.0%	6.0%

ADJUSTMENT FACTORS

Brush Factor For light clearing conditions where the growth consists mainly of brush and small trees, multiply the curves by the following factor:

Brush factor $(Y_{B\ LIGHT}) = 0.25$

For heavy clearing conditions, defined as when clearing a dense growth of trees (diameter of the trees commonly exceeding 0.33 m), multiply the curves by the following factor:

Brush factor $(Y_{B\ HEAVY}) = 1.75$

Side Slope Factor For clearing on terrain with side slopes other than 20% to 50% multiply the curves by the following factors:

For clearing on terrain with side slopes of 0% to 20%,

Side slope factor $(Y_{S\ 0\%-20\%}) = 0.8$

For clearing on terrain with side slopes of 50% to 100%,

Side slope factor $(Y_{S\ 50\%-100\%}) = 1.2$

For clearing on terrain with side slopes greater than 100%,

Side slope factor $(Y_{S\ +100\%}) = 2.5$

Burning Factor When the burning of cleared brush and trees is prohibited due to environmental regulations, the brush and trees will have to be stacked or buried. If burning is prohibited, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.2$

Supply factor $(F_S) = 0.2$

Equipment operation factor $(F_E) = 1.2$

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation value by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

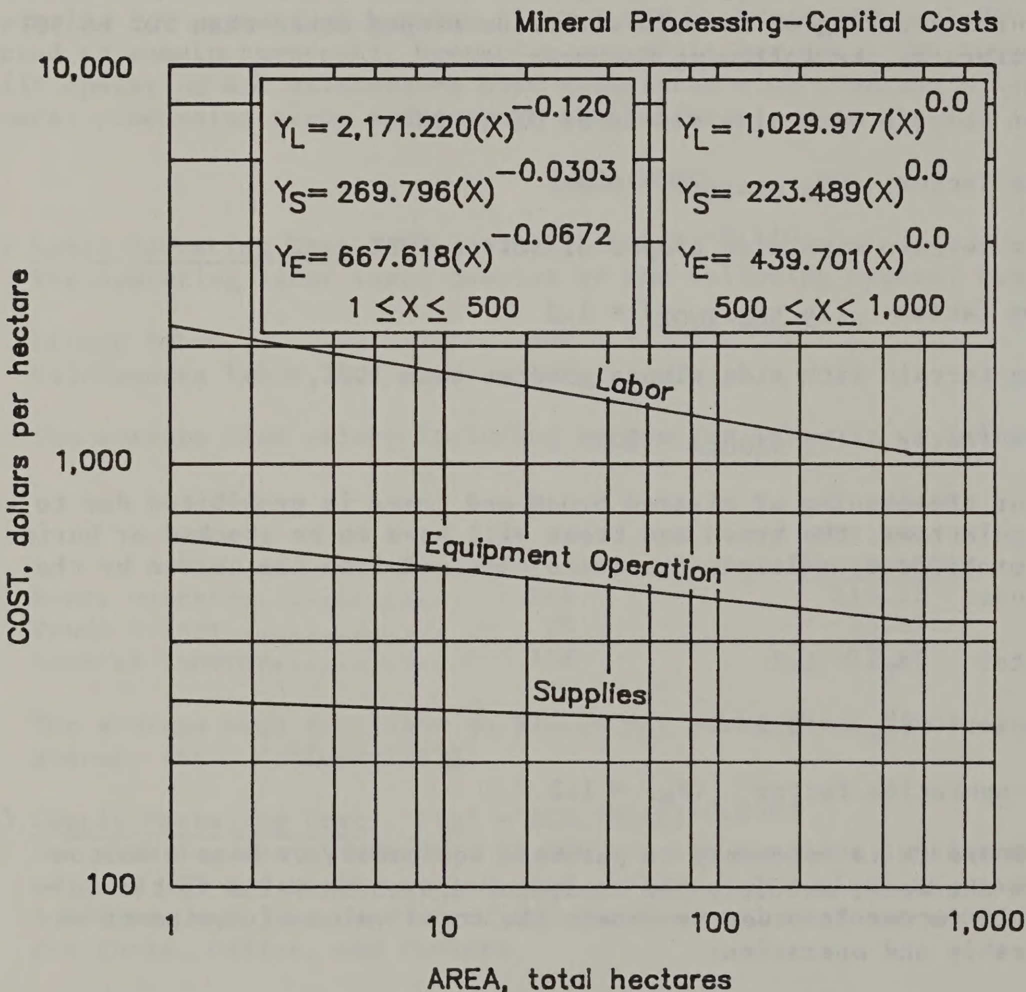
Shifts per day.............	1	2	3
Factor.....................	1.56	1.42	1.37

Subcontractor Factor If a subcontractor is used, multiply the costs obtained from the curves by the following factors to compensate for subcontractor's markup:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



6.1.8.1. Clearing

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.3. EARTHFILL DIKES AND SMALL DAMS

Dikes and/or small dams used to contain waste and tailings vary with the terrain and materials to be used, and must meet the regulations for small dam construction. Construction is accomplished using scrapers having an on-site material haul distance between 600 and 1,500 m. No allowance has been made for transport or purchase of suitable fill material. If these costs are not a part of other mining and/or milling operations, the user must determine the cost of fill material. The total cost is based on a single curve having a total embankment (X), in cubic meters of material. The curve is valid for operations between 5,000 and 500,000 m^3, operating two shifts per day.

BASE CURVE

The earthfill dikes and small dams capital cost derived from the curve is a combination of the following costs:

Construction labor cost........	53%
Construction supply cost....... (fill material not included)..	5%
Purchased equipment cost.......	42%

A typical breakdown of the major cost components is

Scrapers.........................	42%
Crawler dozers...................	26%
Compactors.......................	18%
Rubber tired support.............	14%

The total earthfill dikes and small dams capital cost is $(Y_C) = 0.014(X)^{1.420}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 0.00726(X)^{1.420}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 0.00069(X)^{1.420}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 0.00575(X)^{1.420}$

The construction labor costs consist of the following typical range of personnel:

Direct labor...............	60%
Maintenance labor..........	40%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Scraper operator...........	24%	$16.33
Dozer operator.............	21%	16.33
Compactor operator.........	23%	16.33
Motor-grader operator......	10%	16.33
Truck driver...............	5%	15.89
Utility worker.............	17%	13.66

The average wage for labor is $16.02 per worker-hour (including burden and average shift differential).

The general equipment operating cost component distribution is as follows:

Description	Repair parts	Fuel and lube	Tires
Scrapers....................	41.0%	41.0%	18.0%
Crawler dozers..............	49.0%	51.0%	-
Compactors..................	55.0%	45.0%	-
Rubber-tired support.......	27.0%	64.0%	9.0%

ADJUSTMENT FACTORS

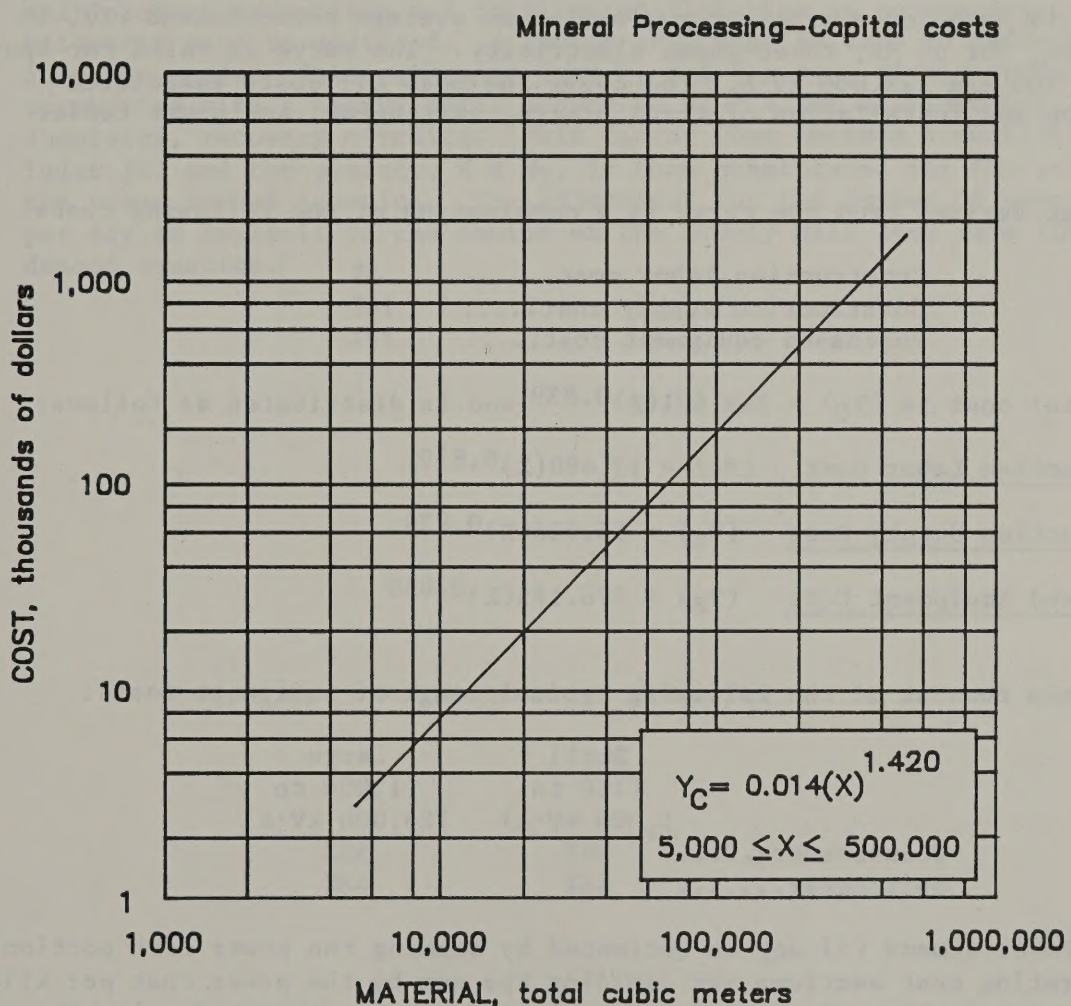
Equipment Factor Where it is necessary to purchase equipment or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

Shifts per day.............	1	2	3
Factor.....................	1.67	1.50	1.48

Subcontractor Factor If a subcontractor is used, multiply the costs obtained from the curves by the following factors to compensate for subcontractor's markup:

Labor factor (F_L) = 1.5

Equipment operation factor (F_E) = 1.2



6.1.8.3. Earthfill dikes and small dams

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.4. ELECTRICAL SYSTEM

The capital cost is for acquisition and installation of the main substation, yard distribution, lighting, and communications for the mill. Major items of equipment include transformers, switchgear, and power lines.

BASE CURVE

The total cost is based on a single curve having an average power demand (X), in kilovolt amperes, for 60 Hz, three-phase electricity. The curve is valid for operations between 100 and 125,000 kV·A. The curve includes all costs associated with acquisition and installation of transformers, switchgear, and power feeder lines.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	5%
Construction supply cost.....	16%
Purchased equipment cost.....	79%

The total capital cost is $(Y_C) = 349.601(X)^{0.839}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 17.480(X)^{0.839}$

(S) Construction Supply Cost $(Y_S) = 55.936(X)^{0.839}$

(E) Purchased Equipment Cost $(Y_E) = 276.185(X)^{0.839}$

The capital costs consist of the following typical range of equipment costs:

	Small (100 to 1,000 kV·A)	Large (1,000 to 125,000 kV·A)
Transformers.....	54%	52%
Switchgear.......	46%	48%

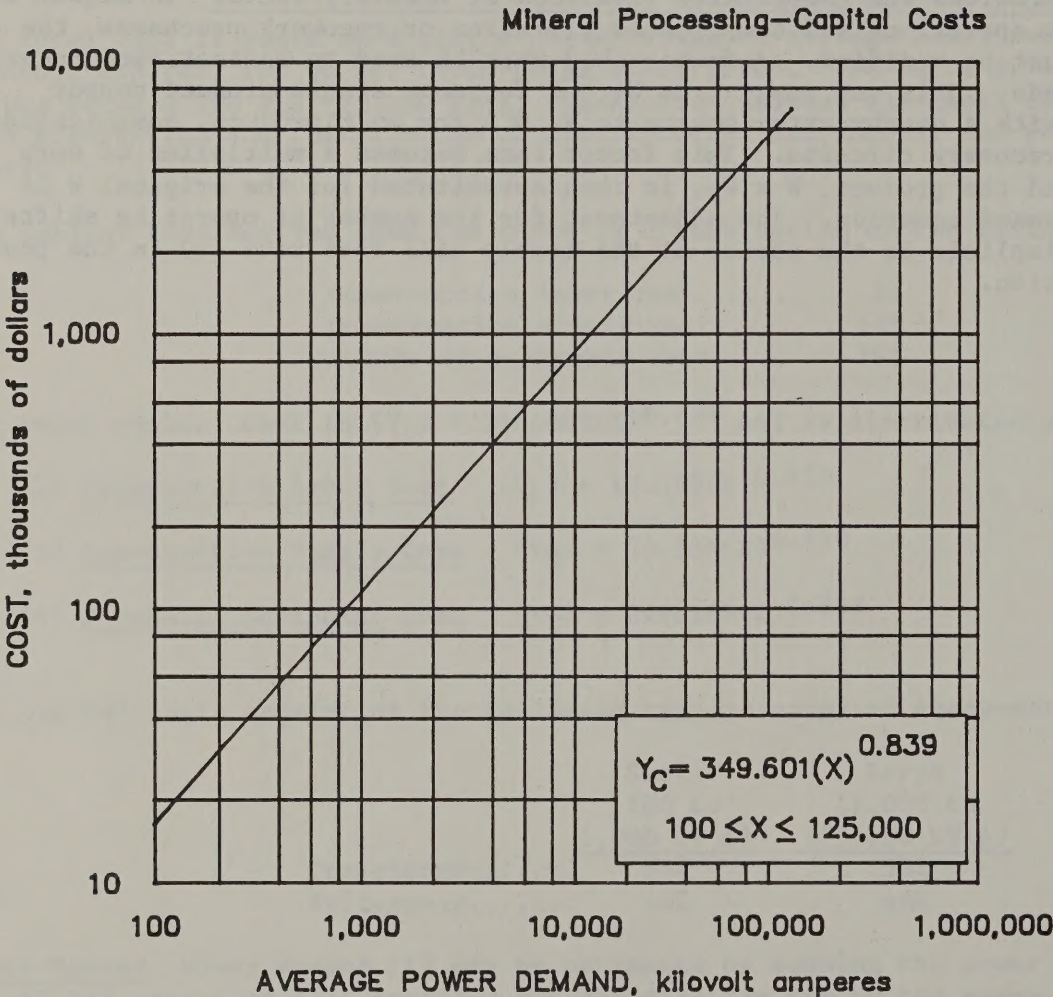
Power Demand Power demand (X) may be estimated by summing the power cost portions of all operating cost sections and dividing the sum by the power cost per kilowatt hour. As an alternate method, power demand may be estimated using the following equation based upon the Bond Work Index.

Power demand $(X) = (11)(Q)(W)(P^{-0.5})$
where X = power demand, in KV•A (if single phase increase by 73%),
Q = feed rate, in metric tons per hour,
W = Bond Work Index of rock being milled (if dry grinding, increase by 33%),
and P = product size, in microns.

NOTE--kilovolt ampere (kV•A) is equivolent to kilowatt (kW); kV•A is commonly used in the power generation industry to designate power demand.

ADJUSTMENT FACTOR

Multiproduct Operations and Complicated Flotation or Recovery Factor To adjust for multiproduct operations and complicated flotation or recovery processes, the kilowatts must be modified. A factor (W_X) must be used to reflect the change in power needs. This can range from $W_X = 1$ for some single-product copper porphyries with a nearby water source to $W_X = 4$ for multiproduct, complicated-chemistry, recovery circuits. This factor then becomes a multiplier of work index (W) and the product, $W \times W_X$, is then substituted for the original W in the power demand equation. The adjustment for the number of operating shifts per day is implicit in the choice of the hourly mill feed rate (Q) in the power demand equation.



6.1.8.4. Electrical system

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.6.2. LOADING FACILITIES
LOAD-OUT FACILITIES

Load-out facility capital costs are based on equipment needed to transport, store, and load-out for shipment concentrates from a mill via truck or train. Total storage capacity is equal to 2 days production of the concentrate from the mill. The load-out facility capital cost includes all costs associated with acquisition and installation of conveyors, storage bins, and bucket elevators. This curve is primarily applicable to low-grade deposits, such as copper or molybdenum deposits. As such, it will cover operations that mine between 2,000 and 60,000 mt of ore per day. The total capital cost is based on a single curve having a production rate (X), in metric tons of concentrate transferred from the mill to storage bins in a 24 h period. The curve is valid for operations between 150 and 1,500 mtpd, operating one shift per day.

BASE CURVE

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	11%
Construction supply cost.....	31%
Purchased equipment cost.....	58%

A typical breakdown of the load-out facility's major cost components is

Bins and activators...........	78%
Bucket elevators..............	7%
Conveyors.....................	15%

The total load-out facility capital cost is $(Y_C) = 5,923.123(X)^{0.568}$ and is distributed as follows:

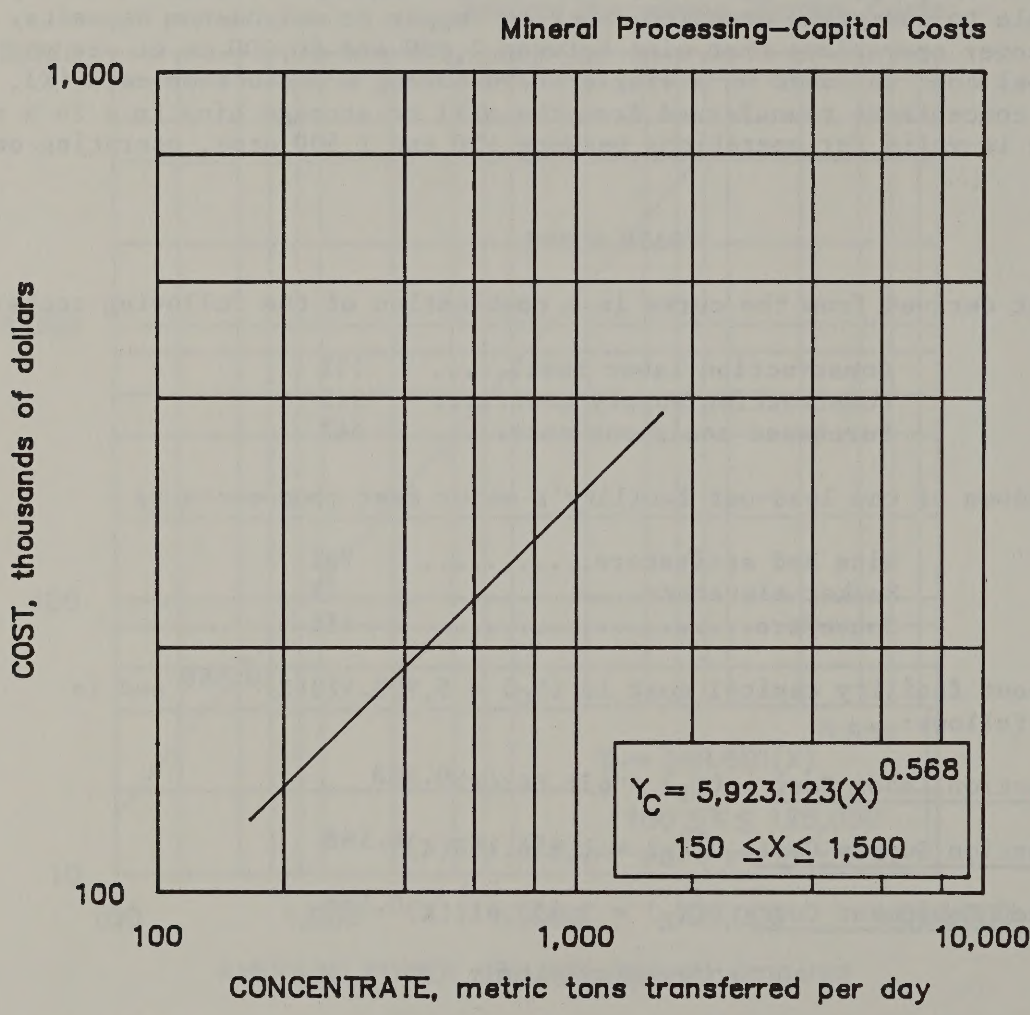
(L) Construction Labor Cost $(Y_L) = 651.543(X)^{0.568}$

(S) Construction Supply Cost $(Y_S) = 1,836.168(X)^{0.568}$

(E) Purchased Equipment Cost $(Y_E) = 3,435.411(X)^{0.568}$

ADJUSTMENT FACTOR

Secondary Concentrate Loadout Milling operations often recover and concentrate secondary minerals such as molybdenum and uranium. The quantities recovered are seldom large in comparison to the primary mineral, running between less than 1 up to 125 mtpd. The basic facilities used for loading out such material usually consist of a small storage bin, a vibrating conveyor used for filling 37 to 55 gallon drums, a roller conveyor for transporting the drums, and a fork-lift for loading drums into trucks or rail cars. These types of facilities are not included in this cost curve. If such operations occur at the proposed mill, the curve must be adjusted accordingly.



6.1.8.6.1. Loading facilities
LOAD—OUT FACILITIES

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.6.2. LOADING FACILITIES
OFF-LOADING FACILITIES

Off-loading facility capital costs are based on installation of equipment used in transporting ore from a reception point to storage bins adjacent to the mill during a two-shift-per-day operation. Storage capacity is between 800 and 12,000 mt of ore. Examples of the types of material stored would be coarse metallic ore, crushed limestone, and coal. For situations where larger storage facilities are needed, see the section 6.8.1.12., stockpile storage facilities. Off-loading facility capital costs includes all costs associated with acquisition and installation of the conveyors, feeders, and storages bins required for this task.

The total capital cost is based on a single curve having a production rate (X), in metric tons of concentrate off-loaded and stored in bins for use by the mill per day. The curves are valid for operations between 800 and 12,000 mtpd, operating two shifts per day.

BASE CURVE

The off-loading facility capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	43%
Construction supply cost.....	45%
Construction equipment cost..	12%

A typical breakdown of the off-loading facility's major cost components is

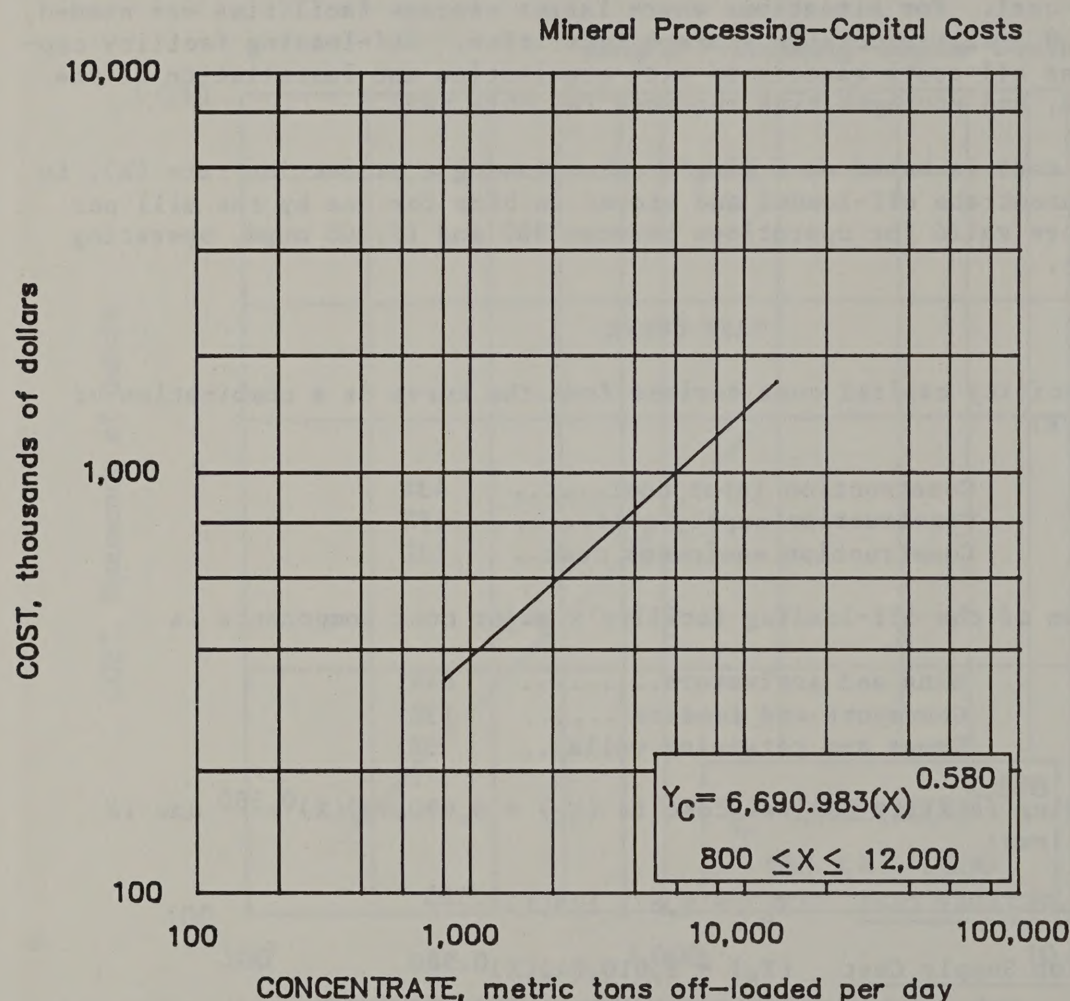
Bins and activators.........	84%
Conveyors and feeders.......	13%
Ramps and retaining walls...	3%

The total off-loading facility capital cost is $(Y_C) = 6{,}690.983(X)^{0.580}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 2{,}877.123(X)^{0.580}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 3{,}010.942(X)^{0.580}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 802.918(X)^{0.580}$



6.1.8.6.2. Loading facilities
OFF–LOADING FACILITIES

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.7. MAIN POWER LINES

If power is to be obtained from a local power company, it is generally necessary to construct new facilities to connect the mine site to the existing power line network. This cost is usually borne by the mine company that desires to receive the service. For shorter distances and lower maximum power loads, this may simply entail extending existing, medium voltage (13- to 24-kV) distribution lines. To satisfy greater loads over longer distances, however, it is necessary to construct higher voltage (115-kV) transmission lines as well as substations dedicated to serve the mine solely. The following tabulation will aid the evaluator in determining the appropriateness of the various options to his particular case.

Main power line distribution

Case	Load Range(MV·A)	Maximum distribution line length, km 24 kV	13 kV	Substation costs
1....	2- 4	105-52	38-19	$ 0
2....	4- 8	52-26	19-10	95,000
3....	8-12	26-18	10- 6	289,000
4....	12-20	18-10	6- 4	630,000
5....	20	0[1]	0[1]	630,000

[1]At greater than 20 MV·A it is advisable to have the main substation at the mine site, thus only transmission lines are considered.

Note--MV·A(million volt amperes) = 1000kW; KV·A(thousand volt amperes) = kW Both MV·A and KV·A are commonly used in the power generation industry to designate power demand.

LINE COSTS:

Transmission lines	$59,000/km
Distribution lines	$42,000/km

It is important to understand that there is an inverse relationship between megavolt amperes and maximum distribution line distances. Thus, in case 2, at 24 kV, the first or lowest load figure (4 MV·A) corresponds to the maximum distance figure (52 km) and the highest load to the lowest distance figure.

It is also important to be aware of a few underlying assumptions regarding the five separate cases. Case 1 shows the power requirement range in which it is likely that existing distribution lines could supply the needed power. Thus there is no substation expense. The second and third cases assume that minor and major modifications of an existing substation will be required, respectively. They also assume that new line needed will originate from that modified substation. For cases 4 and 5 the large power requirements necessitate the construction of a completely new, dedicated substation. This facility will thus have to be fed by extending an existing high-voltage, transmission line. In the instance of case 4 the site of the substation is as near the existing transmission line network as practicable; for case 5 the substation is assumed to be at the mine site.

The costs contained in this section assume that the power company that will be

supplying the power will design and construct the line. Principal costs categories included are right-of-way purchase and clearing, access road construction, line and substation construction, permitting, and preconstruction design.

The procedure for determining the system cost and requirements are as follows:

1. Estimate the maximum power demand that the mine will require. If not available an estimate of this value may be made by the techniques contained in the appropriate mine and beneficiation electrical system sections contained in this handbook. It is recommended that, for estimating, horsepower and kW (or KV•A) be considered to be equivalent. Motor efficiencies as well as other system power losses generally account for much of the difference between the two units.
2. Contact the probable power supplier to determine the "nearest useable source", or likeliest point from which power may be obtained. Depending upon present loading within the system this may or may not be the nearest transmission or distribution line.
3. Calculate the actual maximum distribution line length on the basis of the projected load using the following equations:

   24 kV load

   Maximum distribution line distance, in kilometers = 210/(P)

   13 kV load

   Maximum distribution line distance, in kilometers = 77/(P)
   where P = power requirements, in megavolt amperes.

4. Determine distribution line costs by multiplying the lesser of either the total length of line required or the maximum length of distribution line as calculated in step 3, by line cost per kilometer ($42,000).
5. Estimate the transmission line cost by multiplying the remaining length of line needed by transmission line cost per kilometer ($59,000). Note that for greater than 20 MV•A it is recommended that transmission lines be installed for the entire distance.
6. Based on megavolt amperes, determine a substation cost from the previous tabulation and add this to the line costs already determined. The combination of line and substation costs is the total main power line cost.

BASE CURVE

System costs have been graphed for three different line distances over the range (X) of 2 to 40 MV•A. These curves are included to aid the manual user who is interested in a very preliminary cost and desires to avoid the procedure outlined above for a more detailed cost determination.

Freight charges from the east coast manufacturing plant to Denver, CO, for the major purchased equipment has been determined to be:

Transformer:	32 mt........................	$7500
Oil breaker:	3 @13 mt each................	$9600

All other equipment and materials are considered to be locally available in Denver, CO.

The total capital cost is based on single curves having power loads (X), in megavolt amperes. The curves are valid for power loads of 2 to 40 MV·A.

The capital cost derived from the curve is a combination of the following costs:

	Small (2 to 20 MV·A)	Large (20 to 40 MV·A)
Construction labor cost......	50%	47%
Construction supply cost.....	50%	37%
Purchased equipment cost.....	-	16%

The total 10-km main powerline capital cost is $(Y_{C\ 10\text{-KM LINE}}) = 207{,}826.608(X)^{0.563}$ and is distributed as follows:

(L) Construction Labor Cost

$(Y_{L\ 10\text{-KM LINE-SMALL}}) = 103{,}913.304(X)^{0.563}$
$(Y_{L\ 10\text{-KM LINE-LARGE}}) = 97{,}678.506(X)^{0.563}$

(S) Construction Supply Cost

$(Y_{S\ 10\text{-KM LINE-SMALL}}) = 103{,}913.304(X)^{0.563}$
$(Y_{S\ 10\text{-KM LINE-LARGE}}) = 76{,}895.844(X)^{0.563}$

(E) Purchased Equipment Cost

$(Y_{E\ 10\text{-KM LINE-LARGE}}) = 33{,}252.257(X)^{0.563}$

The total 25-km main powerline capital cost is $(Y_{C\ 25\text{-KM LINE}}) = 644{,}990.250(X)^{0.370}$ and is distributed as follows:

(L) Construction Labor Cost

$(Y_{L\ 25\text{-KM LINE-SMALL}}) = 322{,}495.125(X)^{0.370}$
$(Y_{L\ 25\text{-KM LINE-LARGE}}) = 303{,}145.418(X)^{0.370}$

(S) Construction Supply Cost

$(Y_{S\ 25\text{-KM LINE-SMALL}}) = 322{,}495.125(X)^{0.370}$
$(Y_{S\ 25\text{-KM LINE-LARGE}}) = 238{,}646.392(X)^{0.370}$

(E) Purchased Equipment Cost

$(Y_{E\ 25\text{-KM LINE-LARGE}}) = 103{,}198.440(X)^{0.370}$

The total 50-km main powerline capital cost is $(Y_{C\ 50\text{-KM LINE}}) = 1{,}526{,}363.387(X)^{0.278}$ and is distributed as follows:

(L) Construction Labor Cost

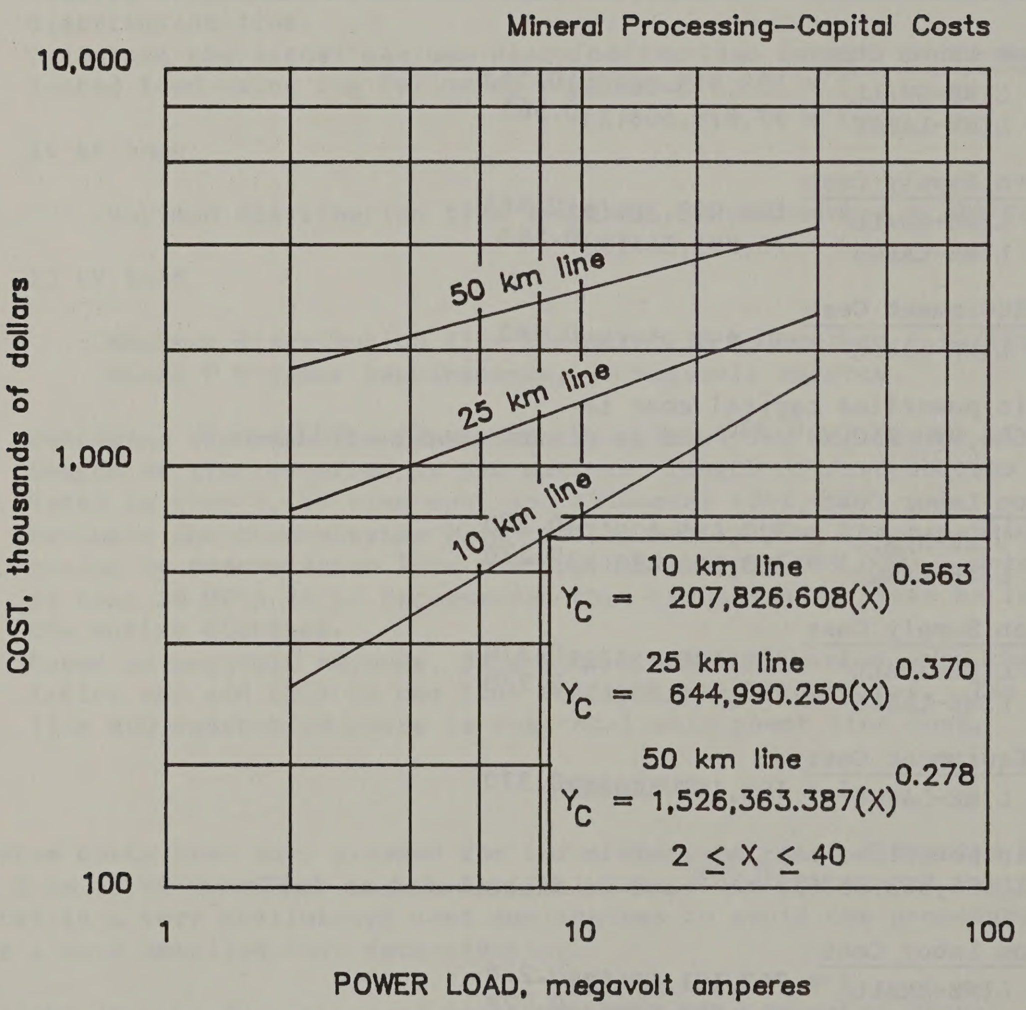
$(Y_{L\ 50\text{-KM LINE-SMALL}}) = 763{,}181.694(X)^{0.278}$
$(Y_{L\ 50\text{-KM LINE-LARGE}}) = 717{,}390.792(X)^{0.278}$

(S) Construction Supply Cost

$(Y_{S\ 50\text{-KM LINE-SMALL}}) = 763{,}181.694(X)^{0.278}$
$(Y_{S\ 50\text{-KM LINE-LARGE}}) = 564{,}754.453(X)^{0.278}$

(E) Purchased Equipment Cost

$(Y_{E\ 50\text{-KM LINE-LARGE}}) = 244{,}218.142(X)^{0.278}$



6.1.8.7. Main power lines

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.8. MILL BUILDINGS

The cost shown is for the mineral processing plant building, or buildings, erected on cleared land.

BASE CURVE

This cost curve is based on a conventional, one-product flotation mineral processing plant and includes foundation and floor excavation, concrete floors and footings, a steel superstructure, electrical and mechanical work, interior lighting, floor gratings and supports, insulation, interior control and instrument rooms, and overhead cranes.

The total capital cost is based on a single curve having an area (X), in square meters of mill building area <u>or</u> on a single cost curve having a production rate (T), in metric tons ore processed per day. The curve is valid for areas of 170 to 31,000 m^2, <u>or</u> 100 to 100,000 mtpd, operating three shifts per day.

If building space requirements are known, the capital cost estimate may be made directly by consulting the cost curve. If space requirements are not known, they can be estimated from the following equation:

Square meters of building space $(X) = 9.390(T)^{0.697}$
where T = ore processed, in metric tons per day.

The mill building capital cost distribution is as follows:

Construction labor cost......	49%
Construction supply cost.....	50%
Purchased equipment cost.....	1%

The mill building section should not be used for processes that do not require building closure, such as limestone calcination.

The total capital cost is $(Y_{C\ \mathrm{SQUARE\ METERS}}) = 3{,}989.552(X)^{0.869}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_{L\ \mathrm{SQUARE\ METERS}}) = 1{,}954.880(X)^{0.869}$

(S) <u>Construction Supply Cost</u> $(Y_{S\ \mathrm{SQUARE\ METERS}}) = 1{,}994.776(X)^{0.869}$

(E) <u>Purchased Equipment Cost</u> $(Y_{E\ \mathrm{SQUARE\ METERS}}) = 39.896(X)^{0.869}$

The total capital cost is $(Y_{C\ MTPD}) = 32{,}407.203(T)^{0.574}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ MTPD}) = 15{,}879.529(T)^{0.574}$

(S) Construction Supply Cost $(Y_{S\ MTPD}) = 16{,}203.602(T)^{0.574}$

(E) Purchased Equipment Cost $(Y_{E\ MTPD}) = 324.072(T)^{0.574}$

ADJUSTMENT FACTORS

Shift Factor To adjust the capital cost for a different number of daily operating shifts, multiply the actual daily tonnage by the ratio of the base number of shifts (three) divided by the number of desired shifts. Then, use this modified production rate in place of actual daily tonnage in the above tonnage, square-meter equation to obtain the adjusted building area. This factor need not be applied if actual building areas are known.

Weather Factor The buildings are based on weather requirements for the Denver, CO, area. For facilities located in climates that vary from the Denver area, multiply the costs obtained from the curve by the following factors:

Mild areas:
Weather factor $(F_{W\ MILD}) = 0.94$

Severe areas:
Weather factor $(F_{W\ SEVERE}) = 1.08$

Open-Sided Building Factor For buildings with open sides, multiply the cost obtained from the curve by the following factor:

Open-sided building factor $F(O) = 0.82$

The weather factor should not be used in combination with this factor.

Soil Factor The curve costs are based on a soil bearing capacity of 6,000 lb/ft^2, which is the safe bearing capacity of loose, medium, or coarse sand, or fine compact sand. For soil bearing capacities other than 6,000 lb/ft^2, multiply the cost obtained from the curve by the appropriate factor in the table below:

Table 8. Soil factors

Safe bearing capacity (10^3 lb/ft^2)	Type of soil	Factor
3	Fine, loose sand or soft clay	1.14
6	Loose, medium or coarse sand, fine compact sand	1.00
10	Compact sand and gravel, hard clay, gravel, coarse sand	0.92
16	Hardpan, soft rock	0.89
24	Shale, medium-hardness rock	0.87
100	Solid hard rock	0.85

Two-Product Factor To obtain the adjusted number of square meters (X_2) for a two-product flotation mineral processing plant, calculate the square meters of building space with the following equation:

Two-product factor (X_2) = $10.235(T)^{0.697}$
where T = ore processed, in metric tons per day.

Then use the adjusted square meters (X_2) in the square-meter-capital-cost equation.

Three-Product Factor To obtain the adjusted number of square meters (X_3) for a three-product flotation mineral processing plant, calculate the square meters of building space with the following equation:

Three-product factor (X_3) = $10.517(T)^{0.697}$
where T = ore processed, in metric tons per day.

Then use the adjusted square meters (X_3) in the square-meter-capital-cost equation.

Copper-Molybdenum Factor To obtain the adjusted number of square meters (X_C) for a copper-molybdenum flotation mineral processing plant, calculate the square meters of building space with the following equation:

Copper-molybdenum factor (X_C) = $11.080(T)^{0.697}$
where T = ore processed, in metric tons per day.

Then use the adjusted square meters (X_C) in the square-meter-capital-cost equation.

Type of Operation Factors For types of operations differing from a conventional crush-grind-float operation, use the following equations to determine the number of square meters (X_O) required, based on capacities in metric tons per day or liters per minute. Then use the adjusted square meters (X_O) in the square meter capital cost equation.

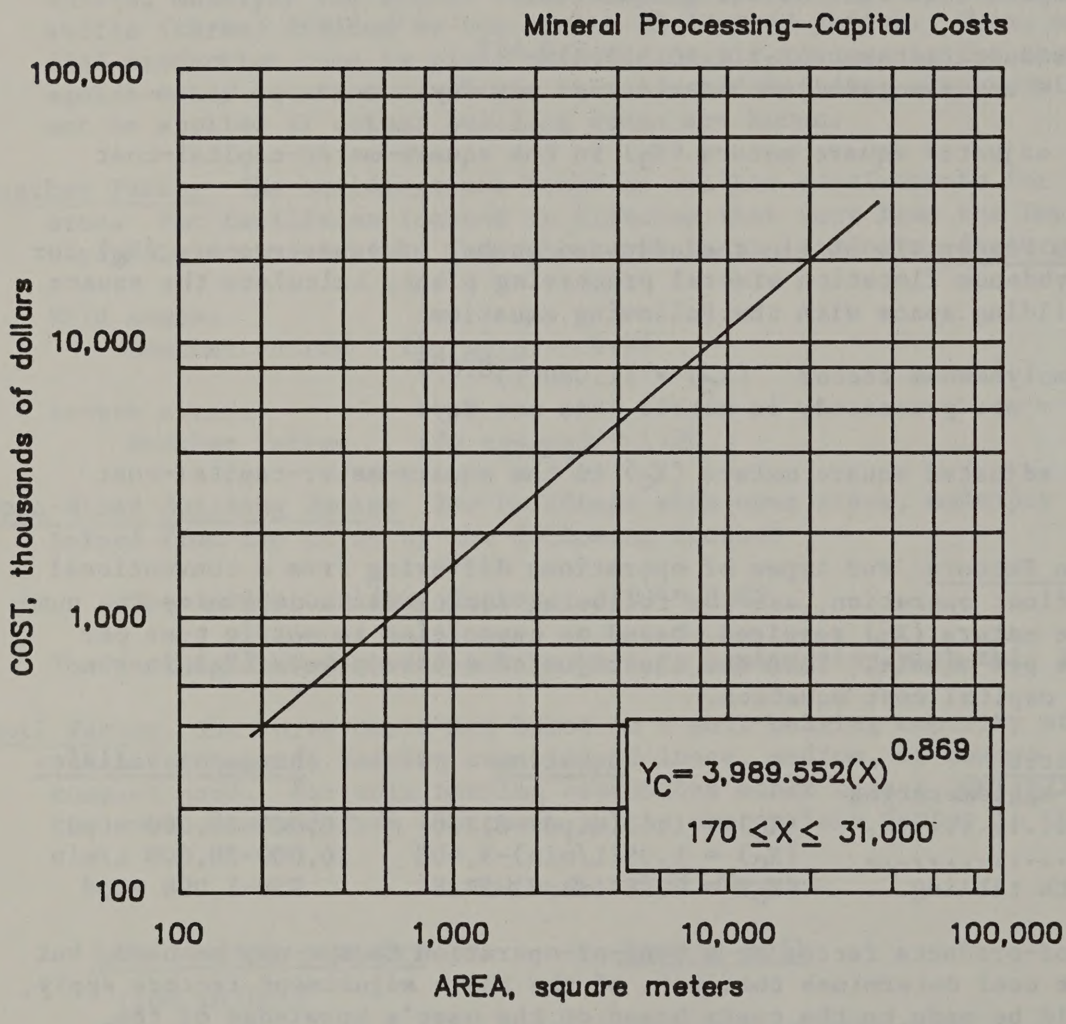
Type of operation	Equation	Range of validity
Concentrator-agglomerating plant....................	(X_O) = 1.13(mtpd)-8,230	10,000-29,000 mtpd
SX-EW....................	(X_O) = 1.09(L/min)-9,400	10,000-20,000 L/min
Flotation with tabling...	(X_O) = 0.267(mtpd)-54.8	950-1,000 mtpd

Either a number-of-products factor or a type-of-operation factor may be used, but not both. If the user determines that none of the above adjustment factors apply, adjustments should be made to the costs based on the user's knowledge of the building requirements.

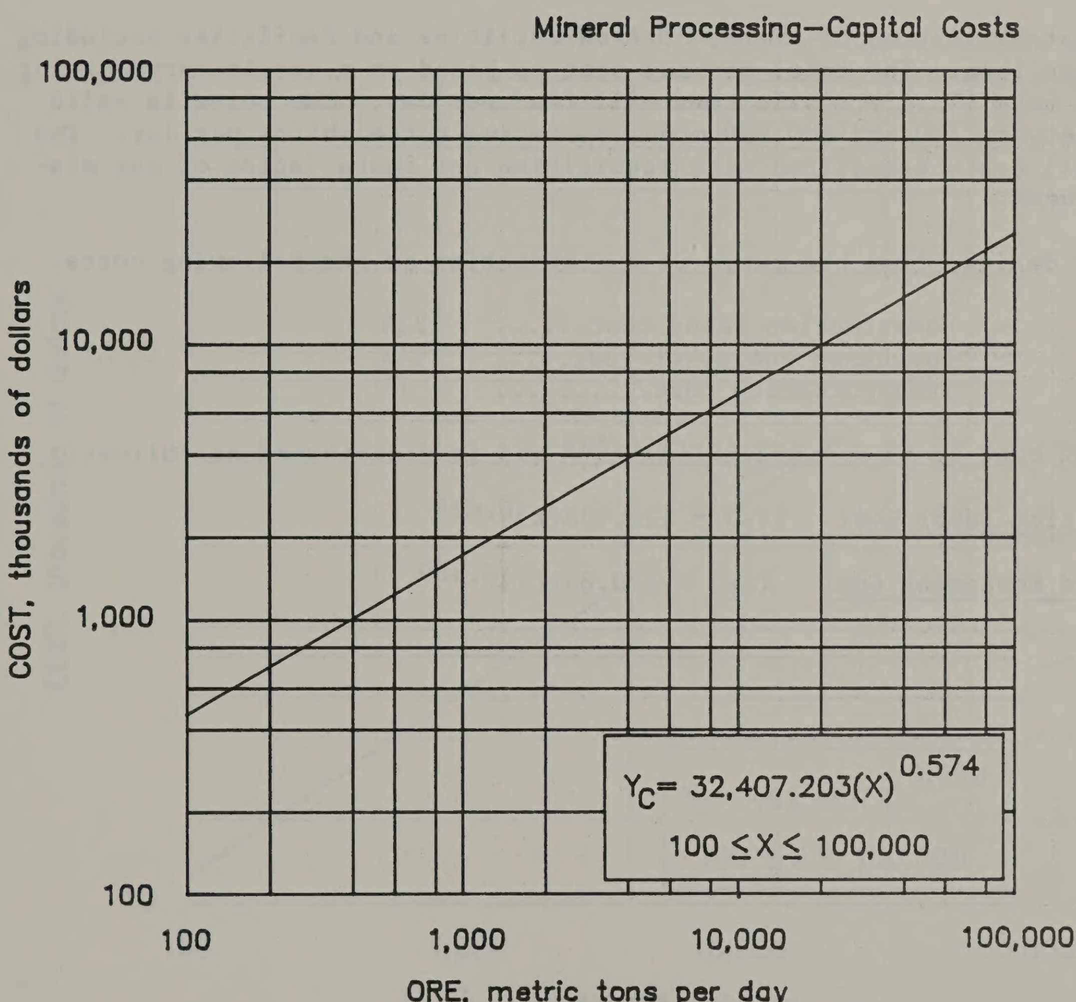
Fine-Ore Bin Factor If fine-ore bins are to be included, add the cost obtained from the curve to the following factor:

Fine-ore bin factor $F_{(F)}$ = $402.000(T)^{0.792}$
where T = feed, in metric tons per day.

To insulate fine-ore bins, add an additional $4/mtpd of feed.



6.1.8.8.a Mill buildings



6.1.8.8.b Mill buildings

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.9. MISCELLANEOUS EQUIPMENT

The capital costs are for nondefined equipment that may be included in some operations and excluded in others. Items in this category would be instrumentation, communications, emergency lighting, standby generators, and special purpose equipment.

BASE CURVE

This curve was established as 5% of the cost of utilities and facilities excluding the mill buildings item. The total capital cost is based on a single curve having an adjusted feed rate (X), in metric tons mill feed per day. The curve is valid for operations between 100 and 100,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition and installation of any miscellaneous equipment.

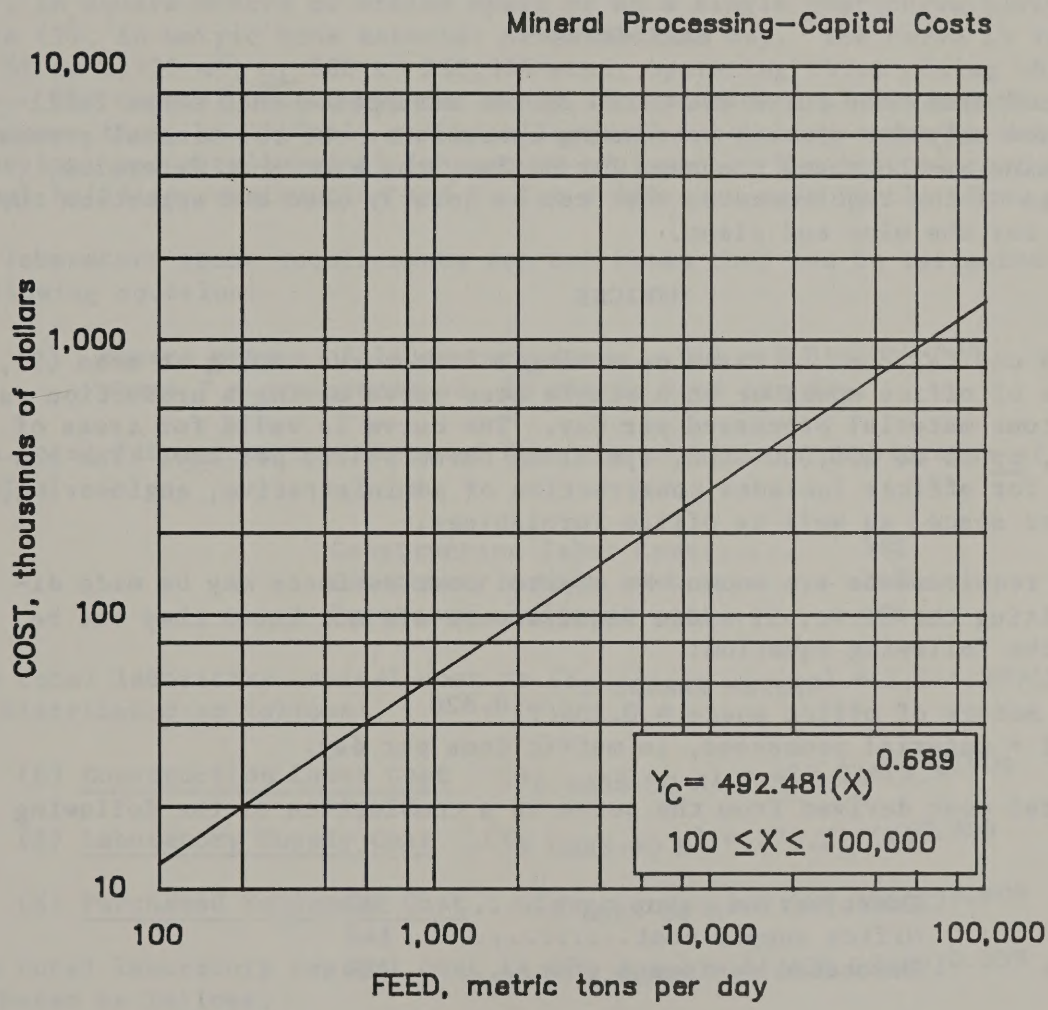
The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	25%
Purchased equipment cost.....	74%
Transportation cost..........	1%

The total capital cost is $(Y_C) = 492.481(X)^{0.689}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_L) = 124.620(X)^{0.689}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 373.861(X)^{0.689}$



6.1.8.9. Miscellaneous equipment

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.10. OFFICES AND LABORATORIES

The cost curve for offices and laboratories includes construction of general offices, engineering and safety offices, and laboratories, including furnishings as well as all necessary assay and metallurgical equipment. Building costs are based on masonry two-story buildings. In this section, office and laboratory capital costs are presented separately.

BASE CURVE

The costs obtained from this curve are based on the assumption that these facilities will be used only for mineral processing operations. If the mineral processing plant and mine are to share the same facilities, the user must determine, using a knowledge of the requirements, what can be jointly used and apportion the resulting costs for the mine and plant.

OFFICES

The total office capital cost is based on a single cost curve having an area (X), in square meters of office space or on a single cost curve having a production rate (T), in metric tons material processed per day. The curve is valid for areas of 8.5 to 4,600 m^2, or 85 to 230,000 mtpd, operating three shifts per day. The capital cost curve for offices includes construction of administrative, engineering, and safety office space, as well as office furnishings.

If office space requirements are known the capital cost estimate may be made directly by consulting the curve; if space requirements are not known they can be estimated from the following equation:

Square meters of office space = $0.206(T)^{0.826}$
where T = material processed, in metric tons per day.

The office capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	38%
Office supply cost...........	14%
Purchased equipment cost.....	48%

The total office capital cost is $(Y_{C\ \mathrm{SQUARE\ METERS}}) = 591.395(X)^{0.979}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ \mathrm{OFFICES-SQ\ M}}) = 224.730(X)^{0.979}$

(S) Office Supply Cost $(Y_{S\ \mathrm{OFFICES-SQ\ M}}) = 82.795(X)^{0.979}$

(E) Purchased Equipment Cost $(Y_{E\ \mathrm{OFFICES-SQ\ M}}) = 283.870(X)^{0.979}$

The total office capital cost is $(Y_{C\ MTPD}) = 125.878(T)^{0.809}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ OFFICES\text{-}MTPD}) = 47.834(T)^{0.809}$

(S) Office Supply Cost $(Y_{S\ OFFICES\text{-}MTPD}) = 17.623(T)^{0.809}$

(E) Purchased Equipment Cost $(Y_{E\ OFFICES\text{-}MTPD}) = 60.421(T)^{0.809}$

LABORATORIES

The total laboratory capital cost is based on a single cost curve having an area (X), in square meters of office space or on a single cost curve having a production rate (T), in metric tons material processed per day. The curve is valid for areas of 51 to 1,725 m^2, or 800 to 230,000 mtpd, operating three mining shifts per day. The capital cost curve for assay laboratories includes construction of sample prepara- tion, analytical, and metallurgical laboratory space as well as crushing, assaying, and metallurgical laboratory equipment. The capital cost is based on steel building construction and is for a lab used only by the mine.

If laboratory space requirements are not known they can be estimated from the following equation:

Square meters of laboratory space $(A) = 8.316(T)^{0.436}$
where T = ore processed, in metric tons per day.

The total laboratory cost derived from the curve is a combination of the following costs:

Construction labor cost......	36%
Laboratory supply cost.......	24%
Purchased equipment cost.....	40%

The total laboratory capital cost is $(Y_{C\ SQUARE\ METERS}) = 1{,}146.989(X)^{0.909}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ LABS\text{-}SQ\ M}) = 412.916(X)^{0.909}$

(S) Laboratory Supply Cost $(Y_{S\ LABS\text{-}SQ\ M}) = 275.277(X)^{0.909}$

(E) Purchased Equipment Cost $(Y_{E\ LABS\text{-}SQ\ M}) = 458.796(X)^{0.909}$

The total laboratory capital cost is $(Y_{C\ MTPD}) = 11{,}670.278(T)^{0.359}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ LABS\text{-}MTPD}) = 4{,}201.300(T)^{0.359}$

(S) Laboratory Supply Cost $(Y_{S\ LABS\text{-}MTPD}) = 2{,}800.867(T)^{0.359}$

(E) Purchased Equipment Cost $(Y_{E\ LABS\text{-}MTPD}) = 4{,}668.111(T)^{0.359}$

ADJUSTMENT FACTORS

Laboratory Shift Factor The square meters of laboratory space required is based on

a three-shift operation. To adjust the capital cost for a different number of daily operating shifts, multiply the actual daily tonnage by the ratio of the base number of shifts (three) divided by the number of desired shifts. Then, use this modified production rate in place of actual daily tonnage in the area versus tonnage equation to obtain the adjusted area. Then, enter the adjusted area in the cost equation to obtain the adjusted capital cost. The square meters of office space is not contingent on the number of shifts and requires no adjustment. If the number of square meters of laboratory space is known, do not use this adjustment factor.

Weather Factor The buildings are based on weather requirements for the Denver. CO, area. For facilities located in climates that vary from the Denver area, multiply the costs obtained from the curve by one the following factors:

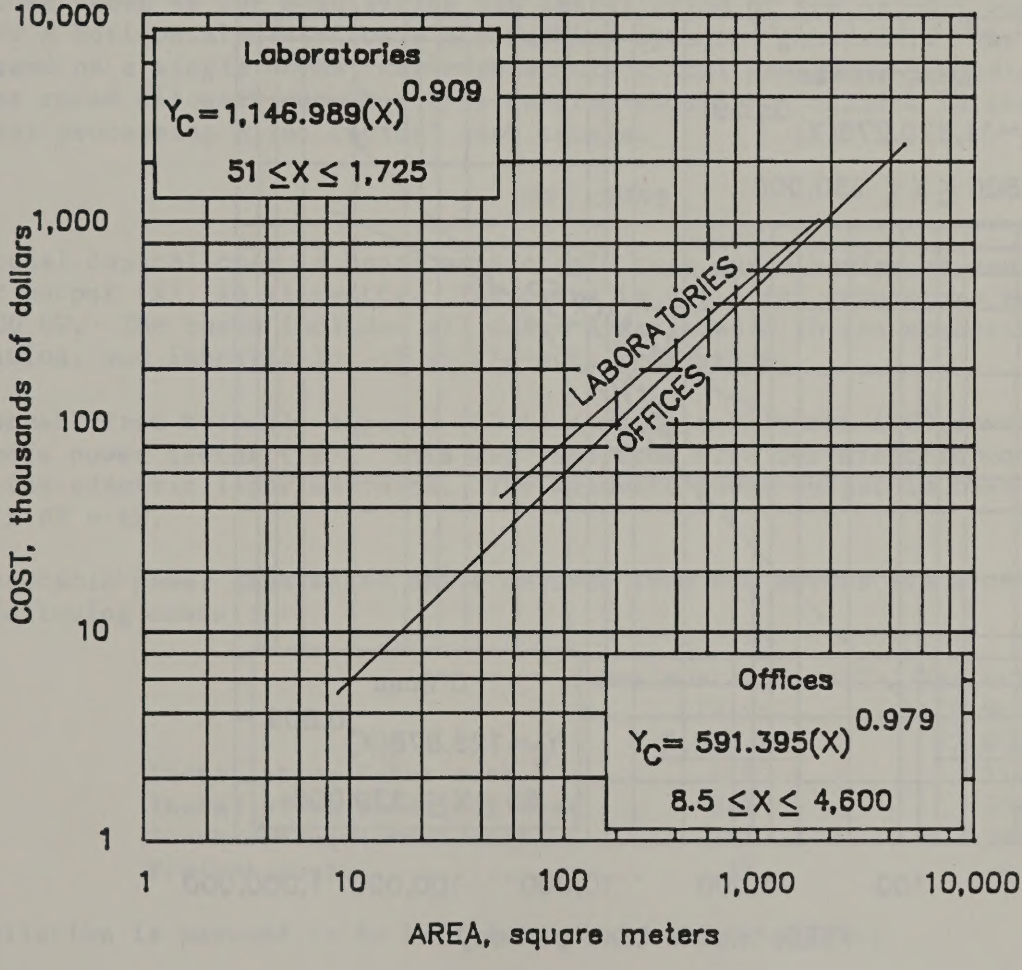
Mild areas:
Weather factor $(F_{W\ MILD}) = 0.94$

Severe areas:
Weather factor $(F_{W\ SEVERE}) = 1.08$

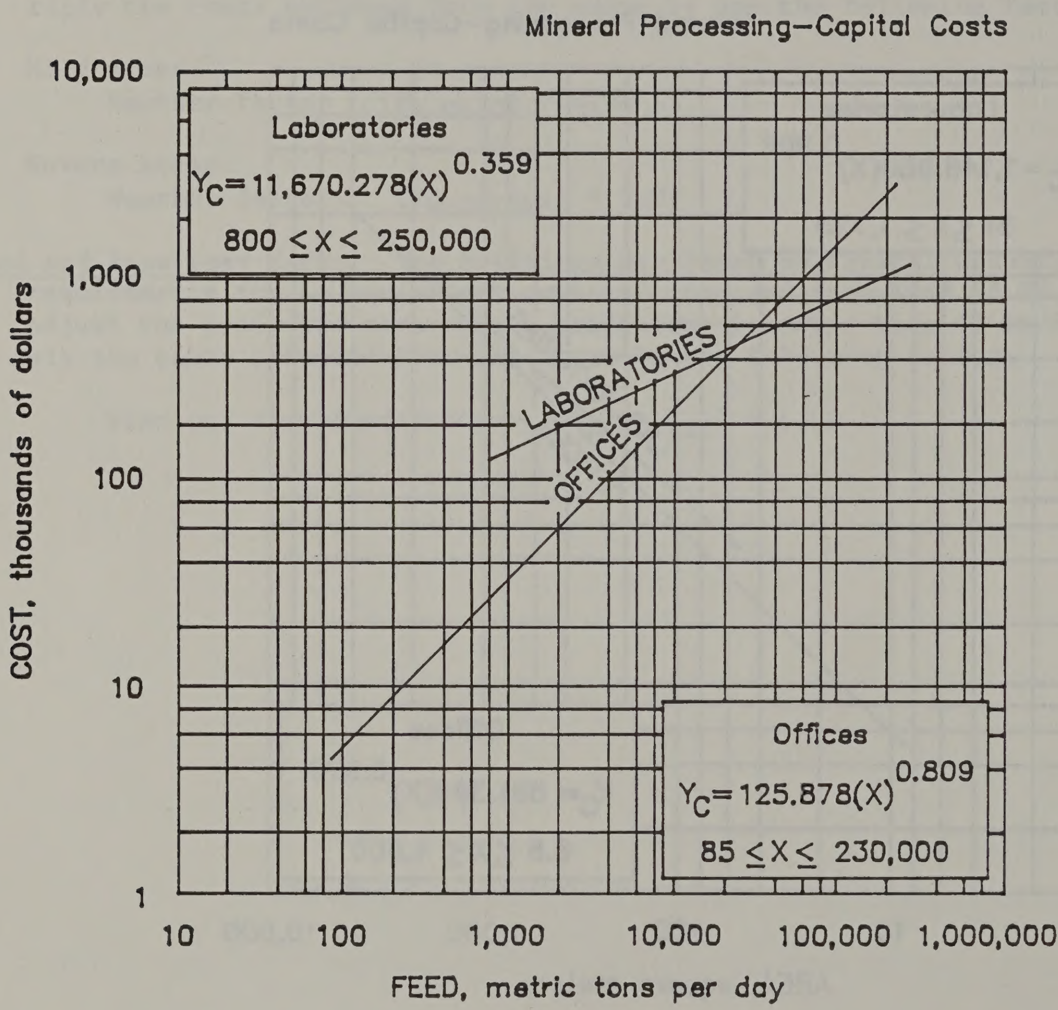
Wind and Snow Load Factor The buildings are based on typical Denver, CO, area requirements for an equivalent combined wind and snow load of 20 lb/ft^2. To adjust the costs for more severe conditions (greater than 40 lb/ft^2), multiply the costs obtained from the curve by the following factor:

Wind and snow load factor $(Y_{W\ SEVERE}) = 1.03$

Mineral Processing—Capital Costs



6.1.8.10.a Offices and laboratories



6.1.8.10.b Offices and laboratories

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.11. PORTABLE POWER GENERATION

This section is to be used in conjunction with section 6.1.8.4. when electrical power is unavailable through a commercial power utility company or when it would be uneconomical to run power distribution facilities to the user. No adjustments are necessary for the mine or mineral processing plant electrical system (sections 2.2.4.2. and 4.2.5.3. (IC 9142), and 6.1.8.4.) because output power matches the power input to the mine/processing plant transformer-switchgear substations.

The cost shown is for acquisition and installation of the primary power source, either a horizontal-diesel or a gas-turbine operated generator. The cost curve is based on a single 60-Hz, three-phase electrical generator providing all power at the rated kilowatt output. This section should be included in the mine and/or mineral processing plant capital cost totals.

BASE CURVE

The total capital cost is based on a single cost curve having an average continuous power output (X), in kilowatts. The curve is valid for generators between 18 to 23,600 kW. The curve includes all costs associated with the acquisition, transportation, and installation of single-unit generators.

To convert from kilovolt amperes (kV·A) demand to kilowatt (kW) power output, estimate power factor (PF). This may vary from 0.80 for electric motor circuits to 1.00 for electric light circuits. The kilowatt power output is then determined by kV·A X PF = kW.

The portable power generation costs derived from the curves are a combination of the following costs::

	Horizontal diesel (18 to 2,900 kW)	Gas turbine (2,900 to 23,600 kW)
Installation labor cost........	21%	21%
Installation materials cost....	20%	20%
Purchased equipment cost.......	58%	59%
Freight cost...................	1%	-

Installation is assumed to be half labor and half materials.

The total diesel-powered portable power generation capital cost is $(Y_{C\ DIESEL}) = 797.574(X)^{0.876}$ and is distributed as follows:

(L) Installation Labor Cost $(Y_{L\ DIESEL}) = 167.491(X)^{0.876}$

(S) Installation Materials Cost $(Y_{S\ DIESEL}) = 159.514(X)^{0.876}$

(E) Purchased Equipment Cost $(Y_{E\ DIESEL}) = 470.568(X)^{0.876}$

The total turbine-powered portable power generation capital cost is $(Y_{C\ TURBINE}) = 2{,}251.219(X)^{0.872}$ and is distributed as follows:

(L) Installation Labor Cost $(Y_{L\ TURBINE}) = 472.756(X)^{0.872}$

(S) Installation Materials Cost $(Y_{S\ TURBINE}) = 450.244(X)^{0.872}$

(E) Purchased Equipment Cost $(Y_{E\ TURBINE}) = 1{,}328.219(X)^{0.872}$

Power Output Determination For surface mine power output (kW), see Electrical System (section 2.2.4.2., IC 9142). For underground mine and mineral processing plant power demand (kV•A), see Electrical System [sections 4.2.5.3., (IC 9142) and 6.1.8.4.]

ADJUSTMENT FACTORS

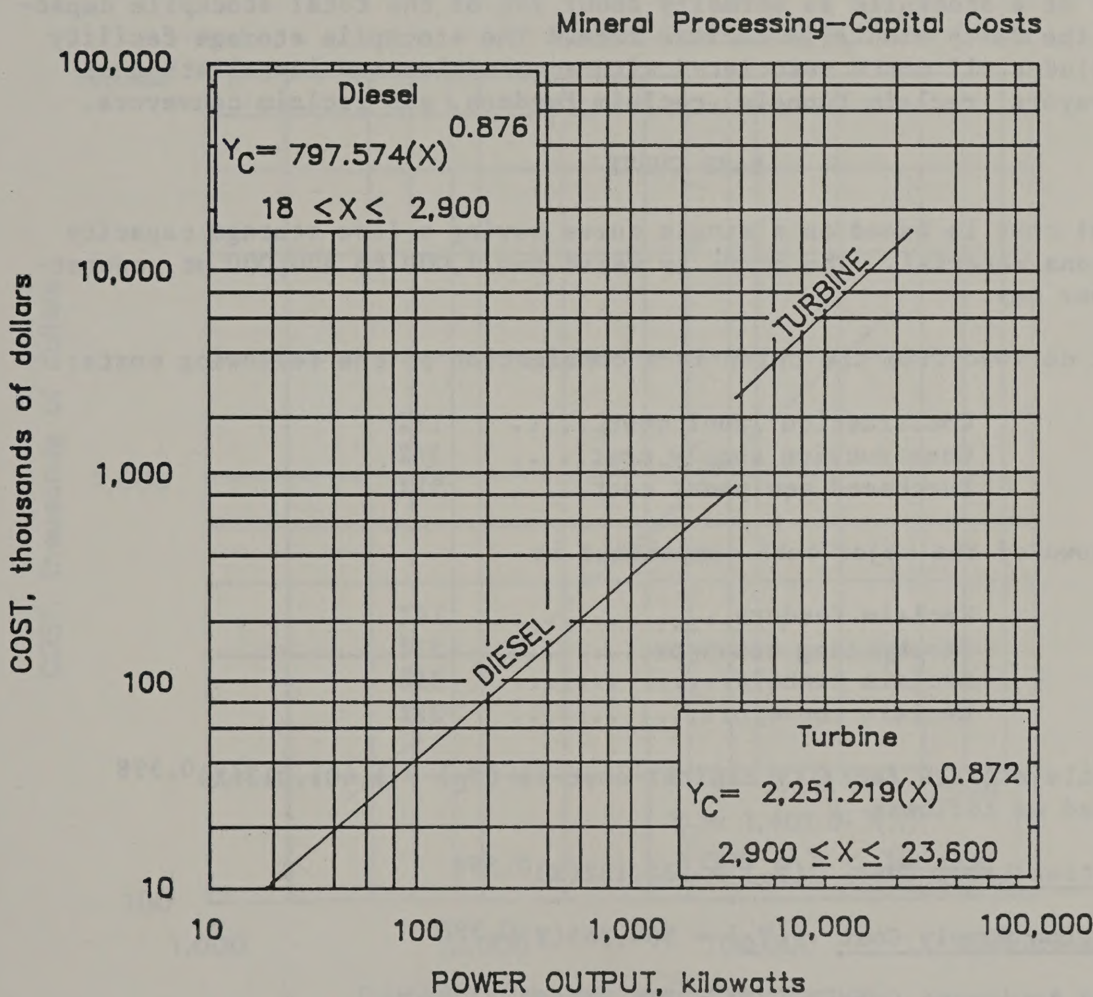
Power Rate If power is to be supplied by more than one unit, the total power output should be divided by the number of required units to obtain the power output per unit (X) needed for entering the curve. After the unit cost has been calculated, the cost must be multiplied by the total number of units used.

Power Source If geography or economics necessitate multiple power sites to support mines and mineral processing plants, portable power cost should be estimated separately for each site using this section.

Economic Life The normal economic life for generators is 25,000 h for units rated at 1,100-kW output or greater and ranges from 11,000 to 17,500 h for units rated at less than 1,100-kW output.

If the units are operated at standby rates, roughly 10% over capacity, the economic life would decrease by 50%.

If high-sulfur fuels are used, the economic life would be decreased by 25%.



6.1.8.11 Portable power generation

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.12. STOCKPILE STORAGE FACILITIES

A stockpile storage facility provides sufficient storage capacity for a material until it can be further processed. A storage facility may also provide adequate reserve material to dampen surges in the material supply. Examples of materials stockpiled are smelter flux, coal, and coarse ore. For this base curve, capital cost is correlated to the live storage capacity of the stockpile facility. Live storage capacity of a stockpile is normally about 25% of the total stockpile capacity and 150% of the daily stockpile reclaim rate. The stockpile storage facility capital cost includes all costs associated with acquisition and installation of stockpiling conveyors, reclaim tunnels, reclaim feeders, and reclaim conveyors.

BASE CURVE

The total capital cost is based on a single curve having a live storage capacity (X), in metric tons material. The curve is valid for 3,000 to 300,000 mt, operating two shifts per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	13%
Construction supply cost.....	36%
Purchased equipment cost.....	51%

A typical breakdown of the major cost components is

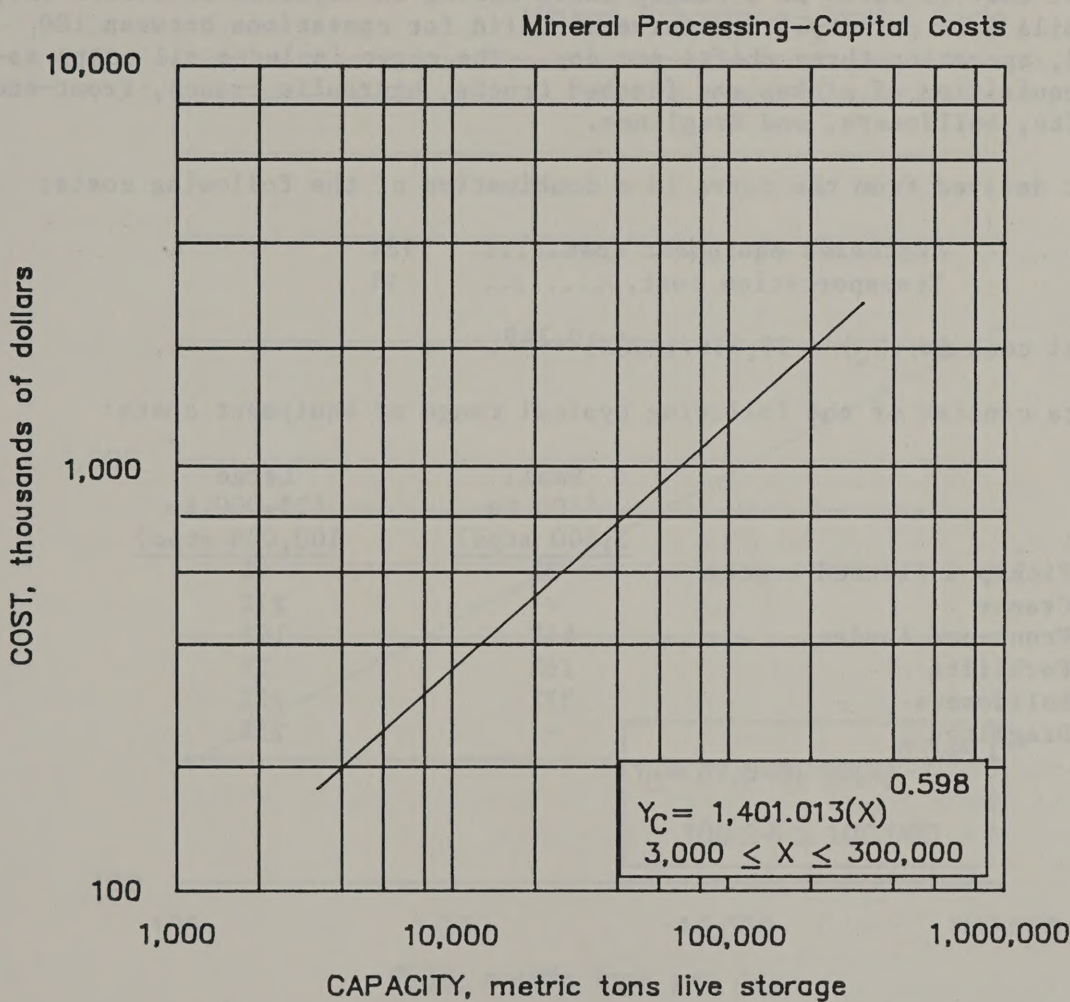
Reclaim feeders.............	14%
Stockpiling conveyor.........	23%
Reclaim tunnels.............	31%
Reclaim conveyors...........	32%

The total stockpile storage facility capital cost is $(Y_C) = 1{,}401.013(X)^{0.598}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 182.132(X)^{0.598}$

(S) Construction Supply Cost $(Y_S) = 504.365(X)^{0.598}$

(E) Purchased Equipment Cost $(Y_E) = 714.516(X)^{0.598}$



6.1.8.12. Stockpile storage facilities

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.13. VEHICLES

The vehicles capital cost is for the acquisition of service vehicles assigned exclusively to the mill.

BASE CURVE

The total capital cost is based on a single curve having an adjusted feed rate (X), in metric tons mill feed per day. The curve is valid for operations between 100 and 100,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition of pickup and flatbed trucks, hydraulic cranes, front-end loaders, forklifts, bulldozers, and draglines.

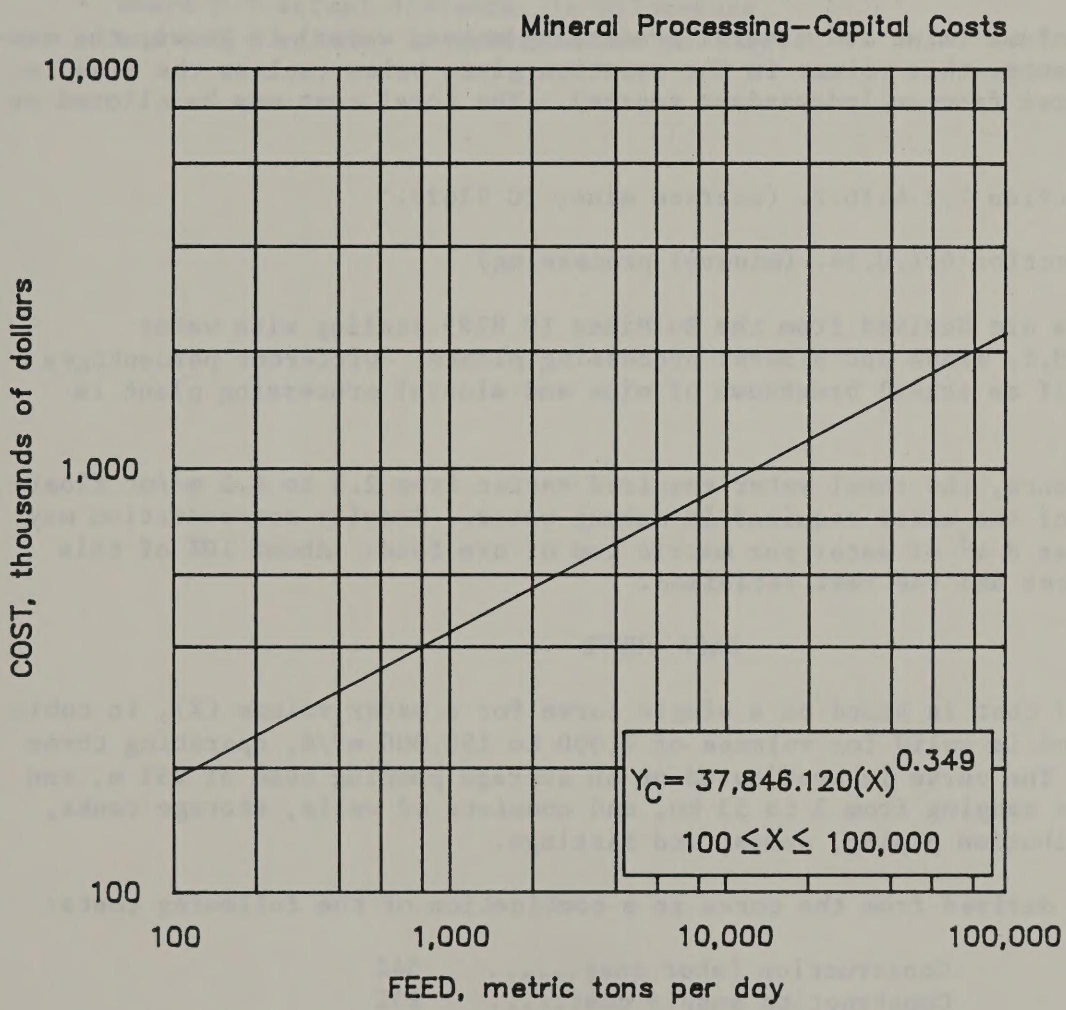
The capital cost derived from the curve is a combination of the following costs:

Purchased equipment cost.....	98%
Transportation cost..........	2%

The total capital cost is $(Y_C) = 37,846.120(X)^{0.349}$.

The capital costs consist of the following typical range of equipment costs:

	Small (100 to 3,500 mtpd)	Large (25,000 to 100,000 mtpd)
Pickup & flatbed trucks	3%	4%
Cranes	-	27%
Front-end loaders	44%	19%
Forklifts	16%	2%
Bulldozers	37%	23%
Draglines	-	25%



6.1.8.13. Vehicles

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.8. GENERAL OPERATIONS

6.1.8.14. WATER SUPPLY SYSTEM (MAKEUP WATER)

Water is supplied from aquifers or surface sources to mineral processing plants primarily for ore processing. Depending on the mineral processing method, the water volume required will vary. The water supply system capital cost for a mineral processing plant (and/or a surface mine, section 2.2.4.10.2., IC 9142) is based on daily water consumption.

If total daily volume (mine and mineral processing makeup water) is known, the manual user should enter this volume in the equation given below (unless the mine is supplied with water from an independent source). The total cost may be alloted as follows:

a) 9% to section 2.2.4.10.2. (surface mine, IC 9142).

b) 91% to section 6.1.8.14. (mineral processing)

NOTE--Percentages are derived from the Bu Mines IC 8285 dealing with water consumption for U.S. mines and mineral processing plants. Different percentages may be obtained if an actual breakdown of mine and mineral processing plant is known.

For flotation plants, the total water required varies from 2.5 to 4.5 m^3/mt floated. Ten to 40% of the water required is makeup water. Gravity concentration may require as much as 8 m^3 of water per metric ton of ore feed. About 10% of this figure is new water and the rest reclaimed.

BASE CURVE

The total capital cost is based on a single curve for a water volume (X), in cubic meters per day and is valid for volumes of 1,000 to 150,000 m^3/d, operating three shifts per day. The curve is predicated on an average pumping head of 291 m, and pumping distances ranging from 3 to 53 km, and consists of wells, storage tanks, pipelines, distribution piping, pumps, and fittings.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	54%
Construction supply cost.....	13%
Purchased equipment cost.....	32%
Freight cost.................	1%

A typical breakdown of equipment major cost components is

Pipeline.....................	58%
Pumps........................	26%
Storage tanks................	16%

The total capital cost is $(Y_C) = 848.677(X)^{0.893}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_L) = 458.286(X)^{0.893}$

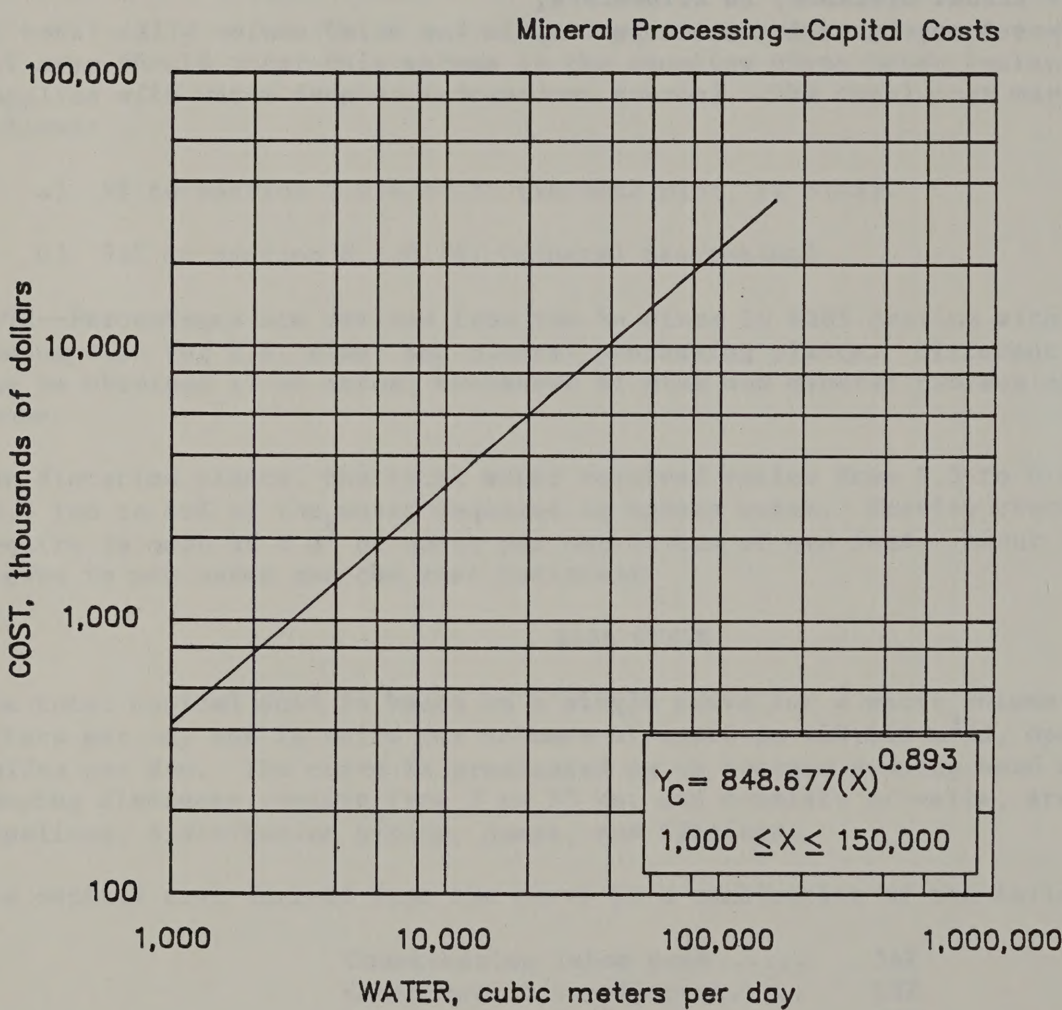
(S) Construction Supply Cost $(Y_S) = 110.328(X)^{0.893}$

(E) Purchased Equipment Cost $(Y_E) = 280.063(X)^{0.893}$

ADJUSTMENT FACTORS

Pumping Distance Factor To adjust the capital cost for actual pumping distances, multiply the cost by the following factor:

Pumping distance factor $(F_D) = 0.03+[12.516(D)(X)^{-0.549}]$
where D = actual distance, in kilometers,
and X = volume, in cubic meters per day.



6.1.8.14. Water and drainage system
WATER SUPPLY SYSTEM (MAKEUP WATER)

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.10. INFRASTRUCTURE

6.1.10.1.1. ACCESS ROADS CLEARING

The total cost per kilometer is the sum of two separate cost curves (labor and equipment operation) having a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with clearing for access roads. Supplies have not been considered in the clearing costs because it is assumed that cleared brush or timber would be buried under the excavation waste; thus, supplies of fuel oil for burning the clearing slash are not required.

BASE CURVE

The curves are based on estimated costs for clearing medium growth on terrain with a side slope of 25%. Medium growth varies from heavy brush to one tree, 0.33 m in diameter, per 40 m^2.

(L) Labor Operating Cost $(Y_L) = 1,135.467(X)^{0.711}$

The operating labor costs are distributed as follows:

Direct labor...............	86%
Maintenance labor..........	14%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dozer operator.............	12%	$16.33
Wheel-loader operator......	12%	16.33
Flatbed-truck driver.......	12%	15.89
General laborer............	64%	13.86

The average wage for labor is $14.63 per worker-hour (including burden and average shift differential).

(E) Equipment Operating Cost $(Y_E) = 467.945(X)^{0.711}$

The equipment operating cost consists of 35% for repair parts, 53% for fuel and lubrication, and 12% for tires.

The equipment operating cost consists of:

Dozer crawler..............	31%
Wheel loader...............	47%
Flatbed truck..............	12%
Pickup truck...............	9%
Chainsaws..................	1%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Dozer crawler.............	52%	48%	-
Wheel loader..............	36%	43%	21%
Flatbed truck.............	9%	80%	11%
Pickup truck..............	8%	90%	2%
Chainsaws.................	39%	61%	-

ADJUSTMENT FACTORS

Brush Factor For light clearing conditions where the growth consists mainly of brush and small trees, multiply the curves by the following factors:

Brush factor $(F_{B\ LIGHT}) = 0.25$

For heavy clearing conditions, defined as when clearing a dense growth of trees (diameter of the trees commonly exceeding 0.33 m), multiply the curves by the following factor:

Brush factor $(F_{B\ DENSE}) = 1.75$

Side Slope Factor For clearing on terrain with side slopes other than 20% to 30% multiply the curves by the following factors:

For clearing on terrain with side slopes of 0% to 20%,

Side slope factor $(F_{S\ 0\%-20\%}) = 0.8$

For clearing on terrain with side slopes of 30% to 50%,

Side slope factor $(F_{S\ 30\%-50\%}) = 1.8$

For clearing on terrain with side slopes of 50% to 100%,

Side slope factor $(F_{S\ 50\%-100\%}) = 2.5$

Burning Equation If fuel oil (for burning slash) or other supplies, such as cables and chokers, are used, add the following supply cost equation to the total cost per kilometer. The total cost per kilometer for supplies is for a roadway of width (X), in meters, varying in width from 3 to 30 m.

(S) Supply Operating Cost $(Y_{S\ BURNING}) = 269.796[0.100(X)]^{-0.0303}$

This cost is multiplied by the total kilometers, valid for values between 3.33 to 3,333.33 km, to obtain the capital cost.

For clearing operations from 1 to 500 ha (roadway width in meters multiplied by roadway length in meters multiplied by 0.0001), the supplies consist of 78% for fuel oil and 22% for tools, cables, and chokers. For clearing operations of 500 to 1,000 hectares, supplies consist of 83% for fuel oil (for burning wood and scrub) and 17% for tools, cables, and chokers.

<u>Equipment Factor</u> Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation value by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

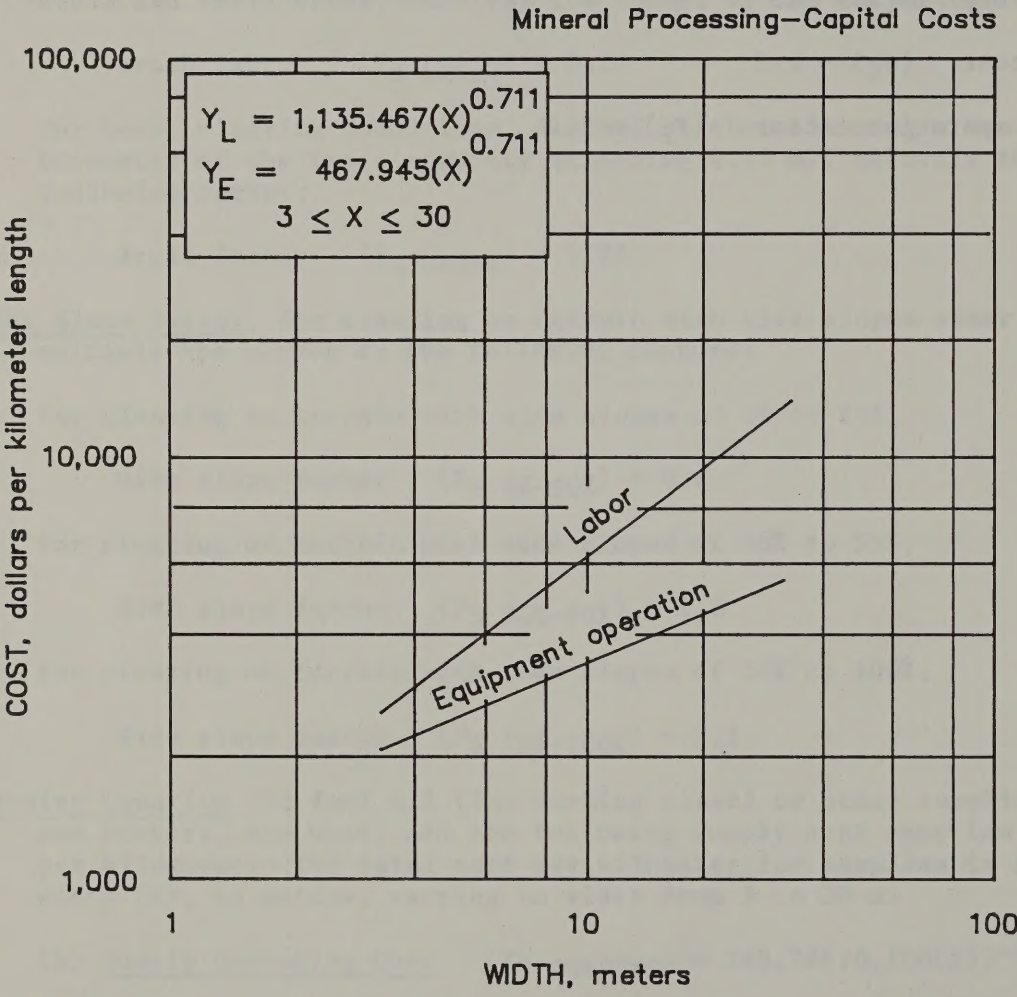
Shifts per day.............	1	2	3
Factor.....................	1.91	1.68	1.61

<u>Subcontractor Factor</u> If a subcontractor is used multiply the costs obtained from the curve by the following factors, to compensate for the subcontractor's markup:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



6.1.10.1.1. Access road
CLEARING

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.10. INFRASTRUCTURE

6.1.10.1.2. ACCESS ROADS
DRILL AND BLAST

The total cost per kilometer is the sum of three separate cost curves (labor, supplies, and equipment operation) having a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with drilling and blasting for access roads.

BASE CURVE

The curves are based on estimated costs for drilling and blasting a cut with a single ditch. The terrain has a side slope of 0% to 20%, and the cut contains 50% rock.

(L) Labor Operating Cost $(Y_L) = 9,633.822(X)^{0.496}$
The operating labor costs are distributed as follows:

Direct labor...............	79%
Maintenance labor..........	21%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Air-track driller..........	33%	$16.78
Compressor operator........	17%	17.23
Chuck tender...............	27%	13.86
Powderman..................	8%	16.33
Powderman helper...........	7%	14.56
Flatbed-truck driver.......	8%	15.89

The average wage for labor is $15.68 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 7,247.524(X)^{0.644}$
The supply cost consists of 79% blasting supplies and 21% drilling supplies. Drilling supplies consist of percussion drill bits, rods, striking bars, and couplings; blasting supplies consist of dynamite, ANFO, electric blasting caps, and connecting wire.

(E) Equipment Operating Cost $(Y_E) = 4,109.384(X)^{0.496}$
The equipment operating cost consists of 51% for repair parts, 48% for fuel and lubrication, and 1% for tires.

The equipment operation curve consists of:

Air-track drills...........	33%
Portable compressors.......	55%
Flatbed truck..............	7%
Pickup truck...............	5%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Air-track drills...........	93%	7%	-
Portable compressors.......	34%	65%	1%
Flatbed truck..............	9%	80%	11%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Rock Factor For drilling and blasting cuts that contain other than 50% rock, multiply the costs obtained from the curves by the following factors:

For drilling and blasting cuts containing 25% rock,

Rock factor $(F_{R\ 25\%}) = 0.6$

For drilling and blasting cuts containing 100% rock,

Rock factor $(F_{R\ 100\%}) = 1.4$

Side Slope Factor For terrain with side slopes other than 0% to 20% multiply the cost obtained from the curves by the following factors:

For clearing on terrain with side slopes of 20% to 50%,

Side slope factor $(F_{S\ 20\%-50\%}) = 1.5$

On terrain with side slopes in the range of 50% to 100%,

Side slope factor $(F_{S\ 50\%-100\%}) = 3.0$

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation value by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

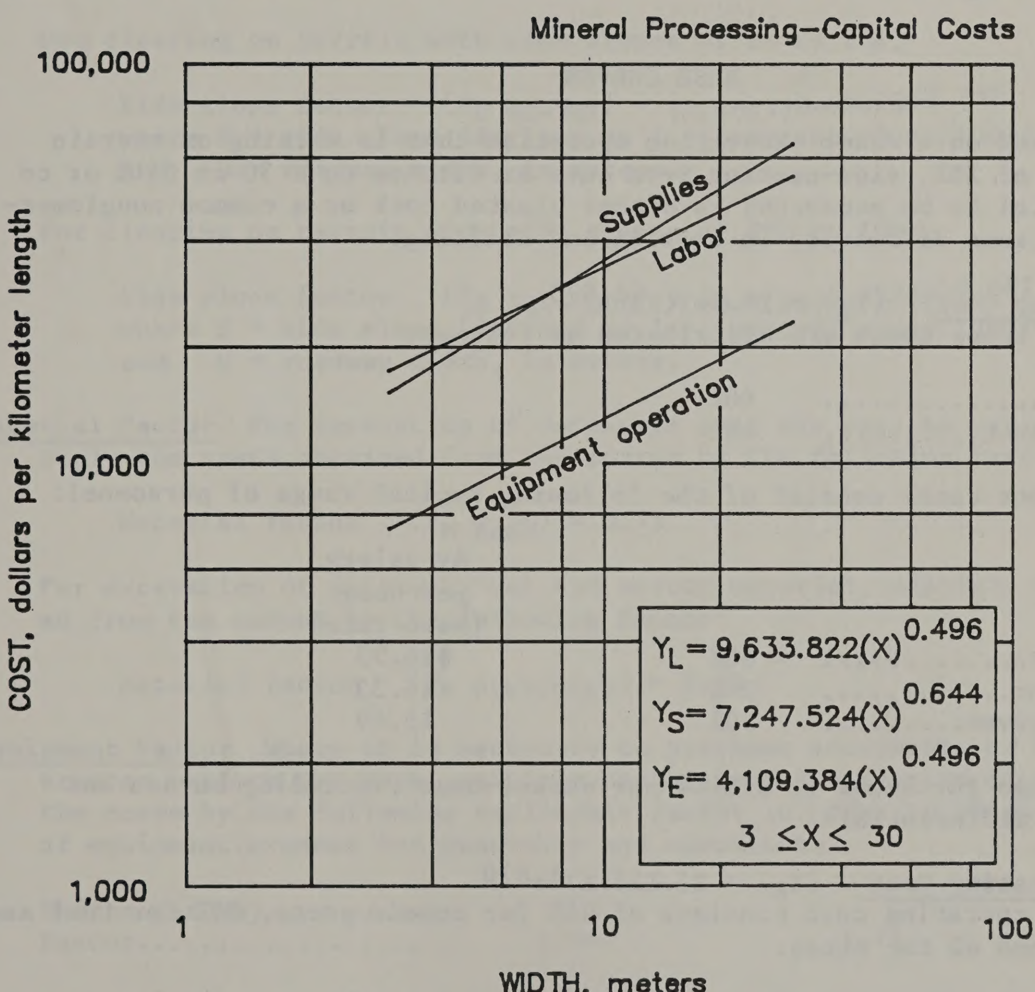
Shifts per day.............	1	2	3
Factor.....................	2.12	1.84	1.75

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs by the following factors:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



6.1.10.1.2. Access roads
DRILL AND BLAST

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.10. INFRASTRUCTURE

6.1.10.1.3. ACCESS ROADS EXCAVATION

The total cost per kilometer is the sum of two separate cost curves (labor and equipment operation) having a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with excavation for access roads.

BASE CURVES

The curves are based on a dozer excavation operation that is working on terrain with a side slope of 25%, side-casting from cuts or ditches to a 30-cm fill or to waste. The material to be excavated is either blasted rock or a common conglomerate that presents some difficulty in cutting and drifting.

(L) Labor Operating Cost $(Y_L) = 29.843(X)^{1.870}$
The operating labor costs are distributed as follows:

Direct labor...............	60%
Maintenance labor..........	40%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dozer operator.............	60%	\$16.33
Grader operator............	20%	16.33
Water-truck driver.........	20%	15.89

The average wage for labor is \$16.24 per worker-hour (including burden and average shift differential).

(E) Equipment Operating Cost $(Y_E) = 27.128(X)^{1.870}$
The equipment operating cost consists of 46% for repair parts, 50% for fuel and lubrication, and 4% for tires.

The equipment operation curve consists of:

Dozer crawlers.............	47%
Dozer-ripper crawler.......	25%
Motor grader...............	15%
Water truck................	9%
Pickup truck...............	4%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Dozer crawlers.............	51%	49%	-
Dozer ripper crawler.......	53%	47%	-
Motor grader...............	45%	41%	14%
Water truck................	29%	55%	16%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Side Slope Factor On terrain with a side slope other than 20% to 30%, multiply the costs obtained from the curves by the following factors:

For clearing on terrain with side slopes of 0% to 20%,

Side slope factor $(F_{S\ 0\%-20\%}) = [0.8(S)]^{0.600}(W)^{0.756}$
where S = side slope [defined as 1 + (percent slope/100)],
and W = roadway width, in meters.

For clearing on terrain with side slopes of 30% to 100%,

Side slope factor $(F_{S\ 30\%-100\%}) = [0.8(S)]^{3.958}(W)^{0.087}$
where S = side slope [defined as 1 + (percent slope/100)],
and W = roadway width, in meters.

Material Factor For excavation of materials that are easy to cut and drift, multiply the costs obtained from the curves by the following factor:

Material factor $(F_{M\ EASY}) = 0.75$

For excavation of extremely wet and sticky material, multiply the costs obtained from the curves by the following factor:

Material factor $(F_{M\ DIFFICULT}) = 1.33$

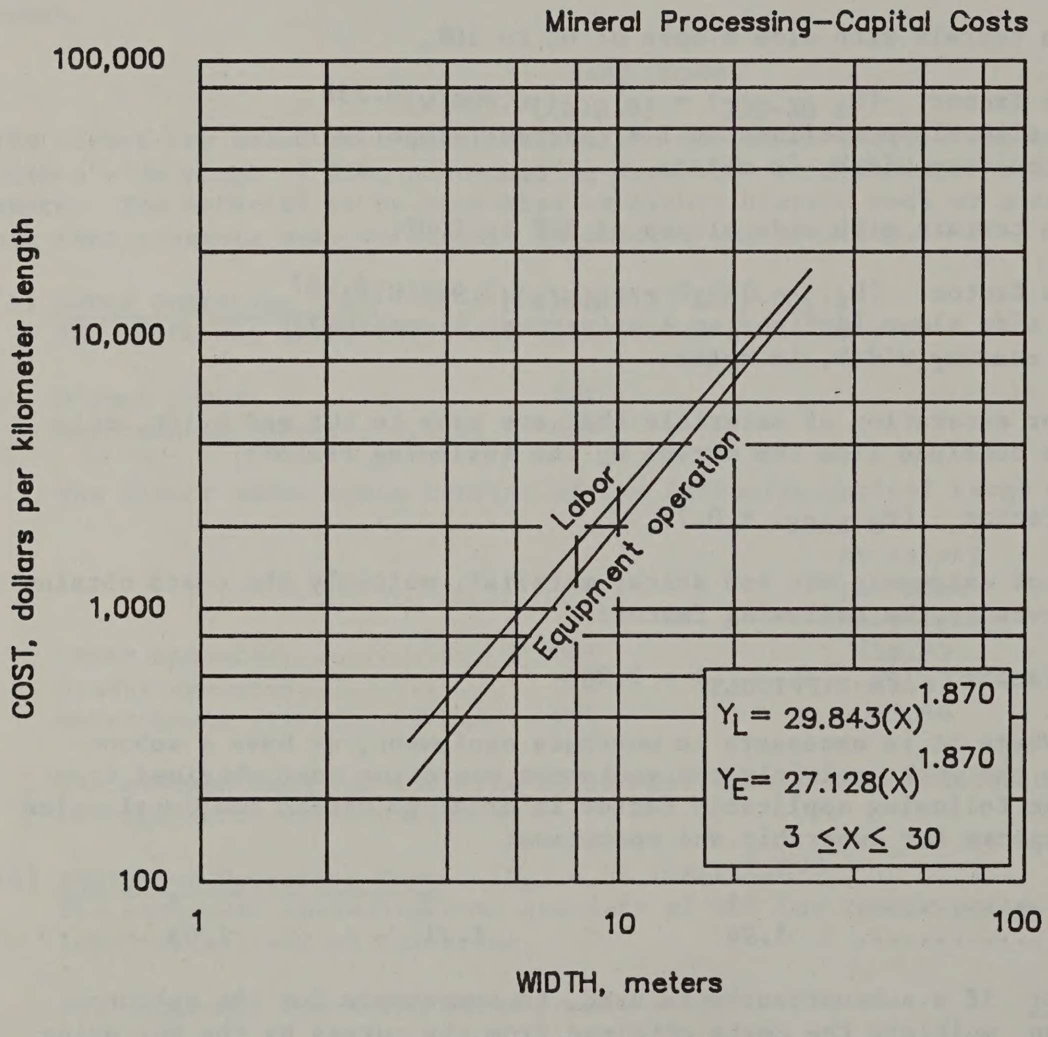
Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

Shifts per day.............	1	2	3
Factor.....................	1.94	1.71	1.63

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.5$

Equipment operation factor $(F_E) = 1.2$



6.1.10.1.3. Access roads
EXCAVATION

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.10. INFRASTRUCTURE

6.1.10.1.4. ACCESS ROADS GRAVEL SURFACING

The total cost per kilometer is the sum of three separate cost curves (labor, supplies, and equipment operation) having a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with gravel surfacing of access roads.

BASE CURVE

The curves are based on costs for preparing a road subbase, spreading surfacing material on the roadway, and compacting the surfacing material to a depth of 0.20 m. The surfacing material is delivered to the jobsite in suppliers' trucks.

(L) Labor Operating Cost $(Y_L) = 293.304(X)^{0.667}$
The operating labor costs are distributed as follows:

Direct labor...............	83%
Maintenance labor..........	17%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Grader operator............	21%	$16.33
Roller operator............	21%	16.33
Dumpman....................	18%	13.86
Grade checker..............	20%	15.89
Water-truck driver.........	20%	15.89

The average wage for labor is $15.66 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 6,880.012(X)^{1.006}$
The supply cost consists of 100% minus 1.9-cm road-surfacing gravel. The gravel, delivered and dumped on the roadbed by suppliers' trucks, costs $13.76 per metric ton.

(E) Equipment Operating Cost $(Y_E) = 135.032(X)^{0.667}$
The equipment operating cost consists of 37% for repair parts, 51% for fuel and lubrication, and 12% for tires.

The equipment operation curve consists of:

Motor grader...............	42%
Rubber-tired, self-propelled roller.....	19%
Water truck................	26%
Pickup truck...............	13%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Motor grader...............	45%	41%	14%
Rubber-tired, self-propelled roller.....	49%	40%	11%
Water truck................	29%	55%	16%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

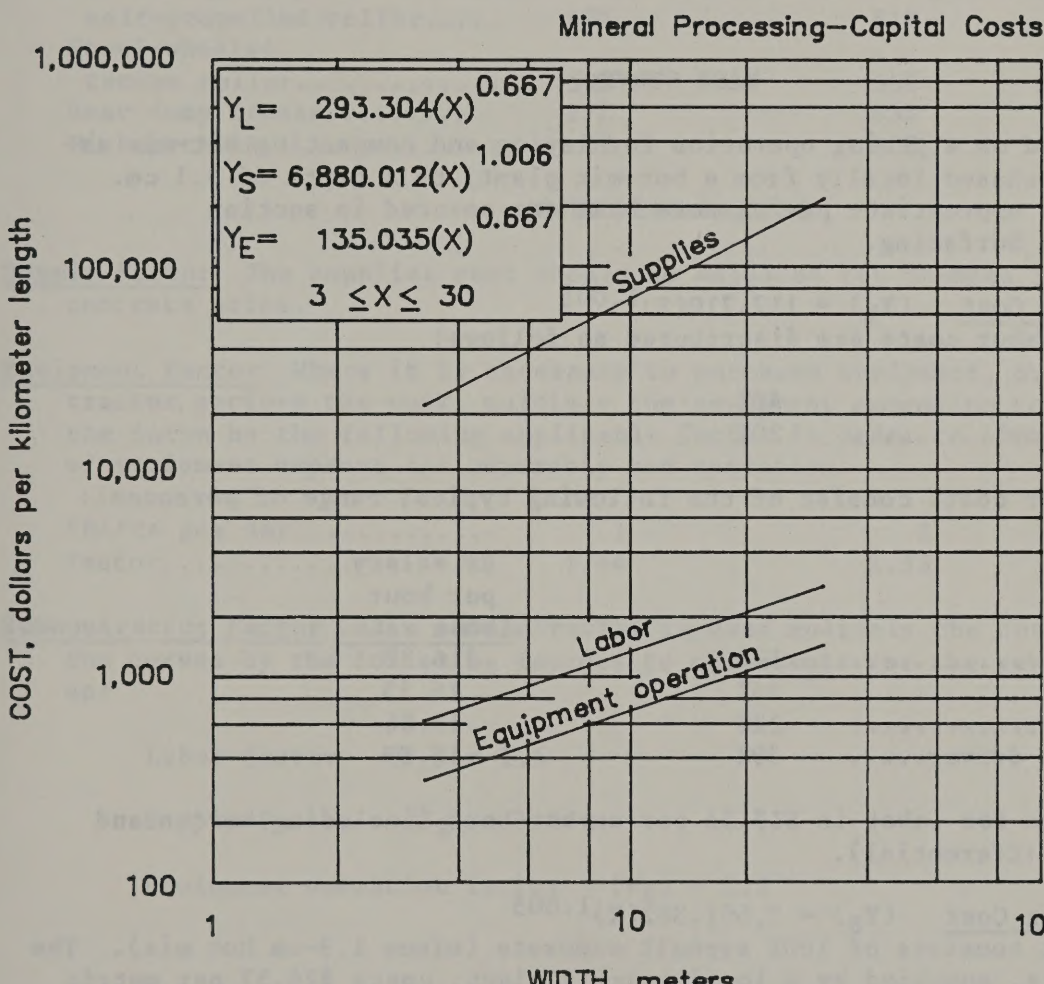
Shifts per day.............	1	2	3
Factor.....................	2.05	1.79	1.70

Subcontractor Factor If a subcontractor is used multiply the costs obtained from the curves by the following factors to compensate for the subcontractor's mark-up:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



6.1.10.1.4. Access roads
GRAVEL SURFACING

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.10. INFRASTRUCTURE

6.1.10.1.5. ACCESS ROADS PAVING

The total cost per kilometer is the sum of three separate cost curves (labor, supplies, and equipment operation) having a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with paving of access roads.

BASE CURVE

The curves are based on a paving operation for laying and compacting hot-mix asphalt concrete (purchased locally from a hot-mix plant) to a depth of 5.1 cm. Costs to produce an appropriate paving road base are covered in section 6.1.10.1.4., Gravel Surfacing.

(L) Labor Operating Cost $(Y_L) = 117.710(X)^{1.005}$
The operating labor costs are distributed as follows:

Direct labor...............	80%
Maintenance labor..........	20%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Paver operator.............	13%	$16.33
Roller operator............	26%	16.33
General laborer............	22%	13.86
Rear-dump truck driver.....	39%	15.89

The average wage for labor is $15.55 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 2{,}661.382(X)^{1.005}$
The supply cost consists of 100% asphalt concrete (minus 1.9-cm hot mix). The asphalt concrete, supplied by a local hot-mix plant, costs $26.37 per metric ton.

(E) Equipment Operating Cost $(Y_E) = 68.436(X)^{1.005}$
The equipment operating cost consists of 32% for repair parts, 58% for fuel and lubrication, and 10% for tires.

The equipment operation curve consists of:

Asphalt paver..............	20%
Rubber-tired, self-propelled roller.....	5%
Steel-wheeled, tandem roller.............	5%
Rear-dump trucks...........	64%
Pickup truck...............	6%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Asphalt paver..............	68%	32%	-
Rubber-tired, self-propelled roller.....	43%	51%	6%
Steel-wheeled, tandem roller.............	50%	50%	-
Rear-dump trucks...........	22%	63%	15%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Supply Factor The supplies cost should be adjusted for changes in the base asphalt-concrete price.

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

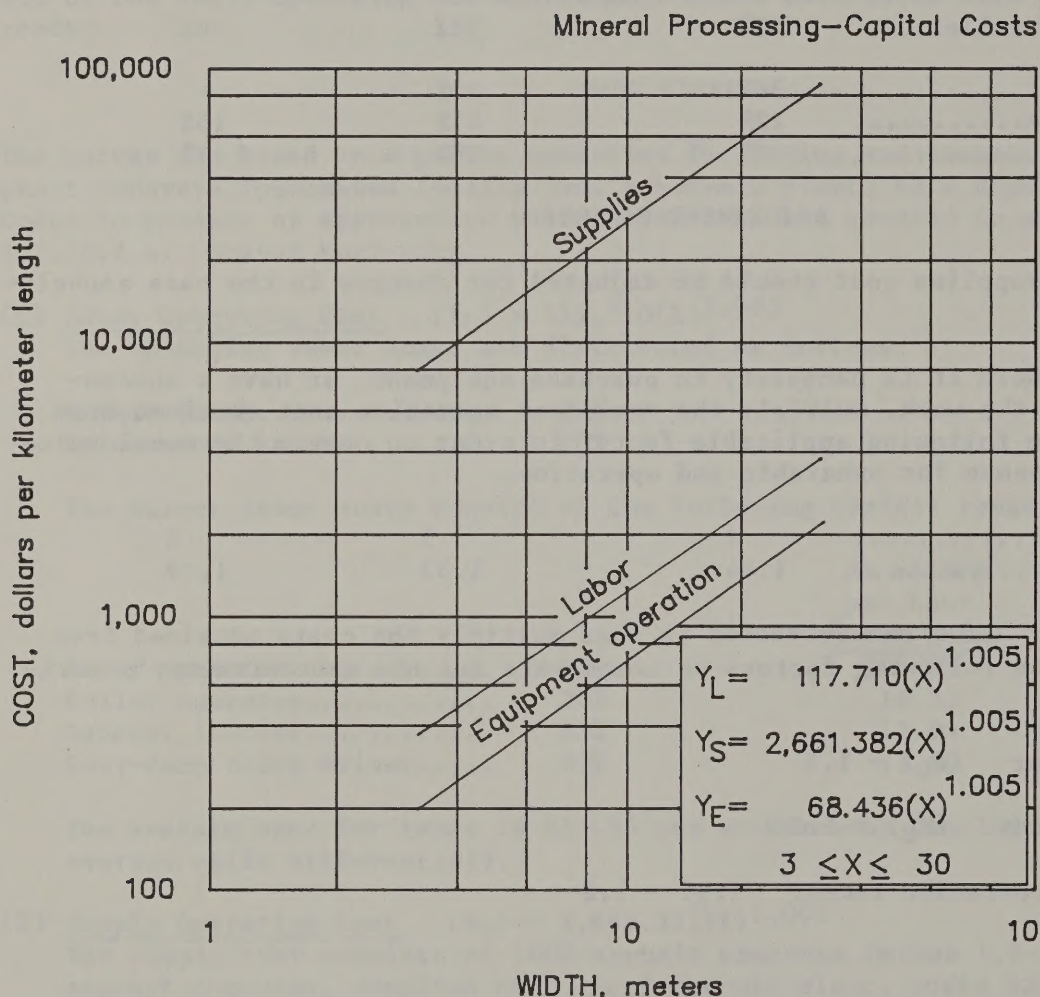
Shifts per day.............	1	2	3
Factor......................	1.44	1.33	1.29

Subcontractor Factor If a subcontractor is used multiply the costs obtained from the curves by the following factors to compensate for the subcontractor's markup:

Labor factor (F_L) = 1.5

Supply factor (F_S) = 1.2

Equipment operation factor (F_E) = 1.2



6.1.10.1.5. Access roads
PAVING

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.10. INFRASTRUCTURE

6.1.10.2. TOWNSITE

The following housing costs are for a typical average quality park based on using trailers or manufactured mobile home housing containing between 150 and 200 units. Costs are quoted per individual housing unit. Costs are factored by using the Bureau of Labor Statistics Industrial Materials Cost Index. Site costs do not include land-site acquisition, construction of utility trunk lines to the site, or a waste water treatment plant. Waste water disposal uses a septic tank and drain field; however, transportation and setup costs to areas within 100 miles of Denver, CO, are included.

Typical average site costs for family or bachelor unit

	Family	Bachelor
Site preparation (typical avg. area 410 m^2).............	$1,050	$320
Streets (7.9- to 9.8-m wide, 7.6-cm asphalt or 7.5-cm gravel edged or curbed)................................	810	270
Patios and walks..	610	200
Septic tank, includes drain field........................	1,360	750
Water, connected to unit.................................	550	550
Gas, low-pressure, connected.............................	310	310
Electrical, 80- to 150-A connected service to each unit..	890	890
Office, recreation, laundry..............................	1,250	1,250
Total..	6,830	4,540

The following adjustment factors should be applied to the total typical average site cost where either quality or quantity differs.

Description	Quality factor	Quantity	Factor
Low quality (300 m^2/space)	0.70	40- 80	1.07
		80-125	1.00
		150-250	0.92
Average (410 m^2/space)	1.00	50-125	1.10
		150-200	1.00
		250-300	0.95
Good (520 m^2/space)	1.30	50-150	1.10
		175-200	1.00
		250-350	0.97

In addition, the following accessories may also be required:

Skirting at base of trailer..................	$620.00
Landing and steps............................	360.00
Canopies over landings.......................	550.00
Air conditioning--using existing heater.......	840.00

HOUSING UNITS

Family Units--With living, dining, kitchen, bath, and sleeping facilities for two adults and two to four children. Cost is for typical average quality.

Single-wide (4.27 by 19.50m)............	$15,400
Double-wide (7.31 by 14.63m)............	$26,400

Quality adjustments to the single-wide, double-wide basic costs are made by multiplying the above housing unit average quality costs by the following factors:

Low quality	
Single wide......	1.12
Double-wide......	1.16
Average	
Single wide......	0.90
Double-wide......	0.87
Excellent quality	
Single wide......	1.25
Double-wide......	1.34

Quantity adjustments--For quantities greater than 10 units, decrease overall costs by 10%.

Snowload adjustment--For areas of heavy snowfall, increase basic unit costs 5% for increased roof support design.

Bachelor Units--Consisting of single-person motel-style rooms with a kitchen and dining room. Rooms share a centrally located restroom and shower facility. Cost is for typical average quality.

Bachelor Unit................................	$15,000

Number of persons adjustment--Per person cost is based on housing 400 personnel. Lodging capital costs for greater than 500 people, decrease costs by 10%. Increase costs by 15% for less than 300 and 20% for less than 200.

PRIMARY UTILITIES

Electrical, cost per linear meter:	
Main overhead electric powerlines..........	$26.32/linear m
Lateral overhead lines.....................	$8.25/linear m
Water, cost per linear meter:	
Main, 15.24-cm plastic (add or deduct $5.75 per 2.54-cm diam.)..................	$35.80/linear m
Lateral, 2.54 cm...........................	$17.22/linear m

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.10. INFRASTRUCTURE

6.1.10.3.1. WASTE WATER TREATMENT CLARIFICATION

Clarification capital cost is for the acquisition and installation of equipment for water clarification and softening by precipitation and/or coagulation. The all metal solids-contact clarifier combines into one operation--quick mixing, flocculation, clarification, and sludge thickening. The unit will selectively or simultaneously remove turbidity, color, organic matter, manganese, iron, hardness, alkalinity, taste, and odor.

BASE CURVES

Total capital cost is based on a single curve having a tank diameter of (X), in meters. The curves are valid for tank diameters between 2.74 to 45.72 m (cross-sectional area ranging from 5.9 to 1,642 m^2), operating three shifts per day. The curve includes all costs associated with acquisition and installation of concrete pad, clarifier structure, and control/monitor equipment for sludge level and sludge density control.

The total clarification capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	19%
Construction supply cost.....	5%
Purchased equipment cost.....	76%

The total clarification capital cost is $(Y_C) = 15{,}631.070(X)^{0.991}$ and is distributed as follows:

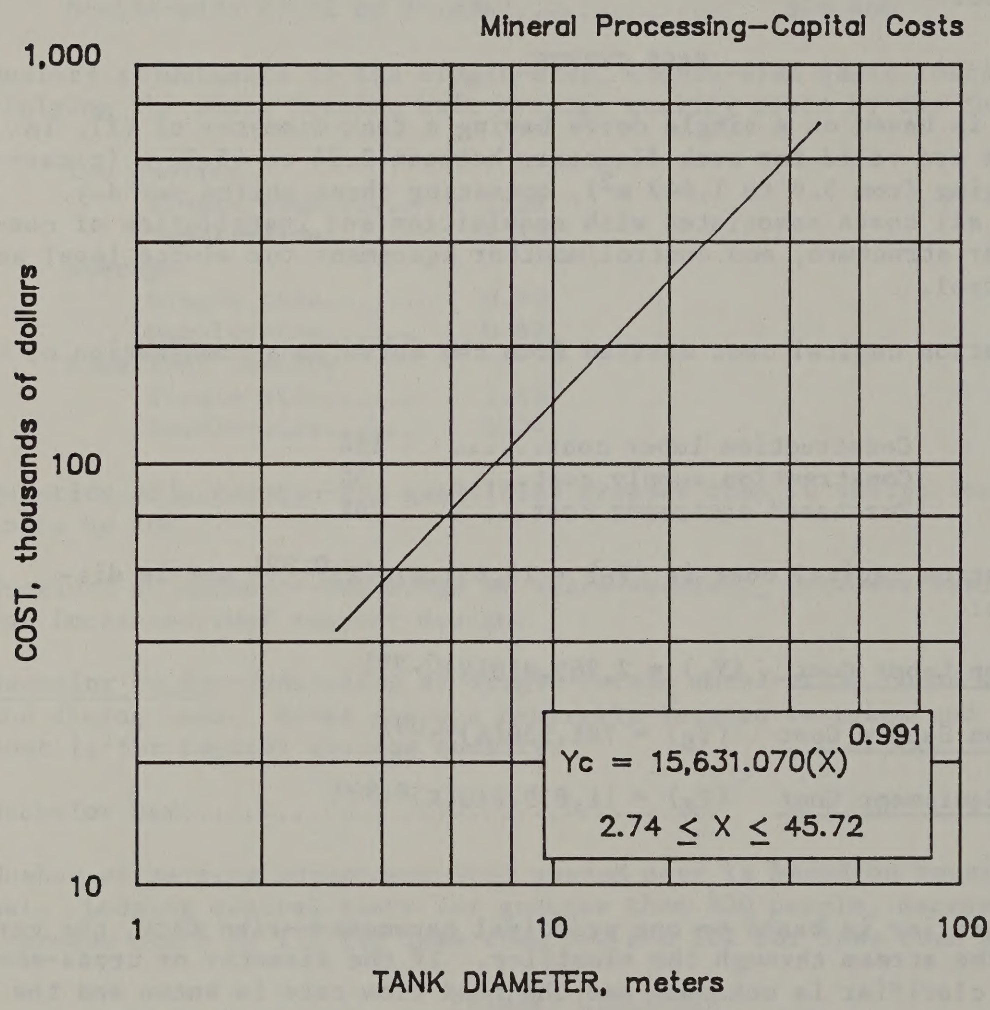
(L) Construction Labor Cost $(Y_L) = 2{,}969.910(X)^{0.991}$

(S) Construction Supply Cost $(Y_S) = 781.550(X)^{0.991}$

(E) Purchased Equipment Cost $(Y_E) = 11{,}879.610(X)^{0.991}$

NOTE--Sizing of clarifier is based on one principal parameter--rise rate, the vertical velocity of the stream through the clarifier. If the diameter or cross-sectional area of the clarifier is unknown, and the feed flow rate is known and the rise rate is assumed to be 0.015 m/min, then the diameter (D), or equivalent cross-sectional area, of the clarifier can be estimated with the equation:

Clarifier diameter $(D) = 1.128[(Q)/(R)]^{0.500}$
where R = rise rate, in meters per minute,
and Q = design flow rate, in cubic meters per minute.



6.1.10.3.1. Wastewater treatment
CLARIFICATION

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.10. INFRASTRUCTURE

6.1.10.3.2. WASTE WATER TREATMENT NEUTRALIZATION

The Environmental Protection Agency's publication EPA-600/2-82-00/d "Treatability Manual, Vol. IV, Cost Estimating," April 1983, was the source of cost development. One is referred to this manual if further detail in neutralization costs is needed. Additionally, other waste water treatment methods are costed in this EPA manual.

The capital cost curves cover neutralization of waste water effluent (out-of-pipe) when required. The basic design variable is waste water flow. Applicability of the curves are for effluent to be neutralized that ranges in volume from 0.001 to 876 L/s (22.8 to 20 million gal/d). It is assumed that flow equalization is provided by a tailings pond. The costs apply to the neutralization of either acidic or basic waste water streams originating from mine, mill, or combined mine and mill after it flows out-of-pipe from the central impoundment pond. In most mining operations further waste water treatment costs are not required. The system consists of chemical addition and two-stage neutralization tanks. It is assumed that pH and suspended-dissolved solid content of influent to the system will be unknown at this level of costing. Basis of design uses a standard dosage of 100 mg/L lime and 100 mg/L acid to achieve a pH of 7.0 over a pH range of 6.5 to 8.0.

BASE CURVES

Total capital cost is based on a single curve having an average waste water flow rate (X), in liters per second. The curves are valid for 0.001 to 876 L/s, operating three shifts per day. The curves include all costs associated with the construc- tion of the treatment facility including mixing tank, attenuation tank, chemical storage, agitators, piping, electrical, and instrumentation.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	22%
Construction supply cost.....	13%
Purchased equipment cost.....	65%

For waste water effluent rates between 0.001 to 8.76 L/s, the capital cost is $(Y_{C\ 0.001-8.76\ L/s}) = 123{,}144.490(X)^{0.094}$ and is distributed as follows:

(L) <u>Construction Labor Cost</u> $(Y_{L\ 0.001-8.76\ L/s}) = 80{,}043.930(X)^{0.094}$

(S) <u>Construction Supply Cost</u> $(Y_{S\ 0.001-8.76\ L/s}) = 27{,}091.780(X)^{0.094}$

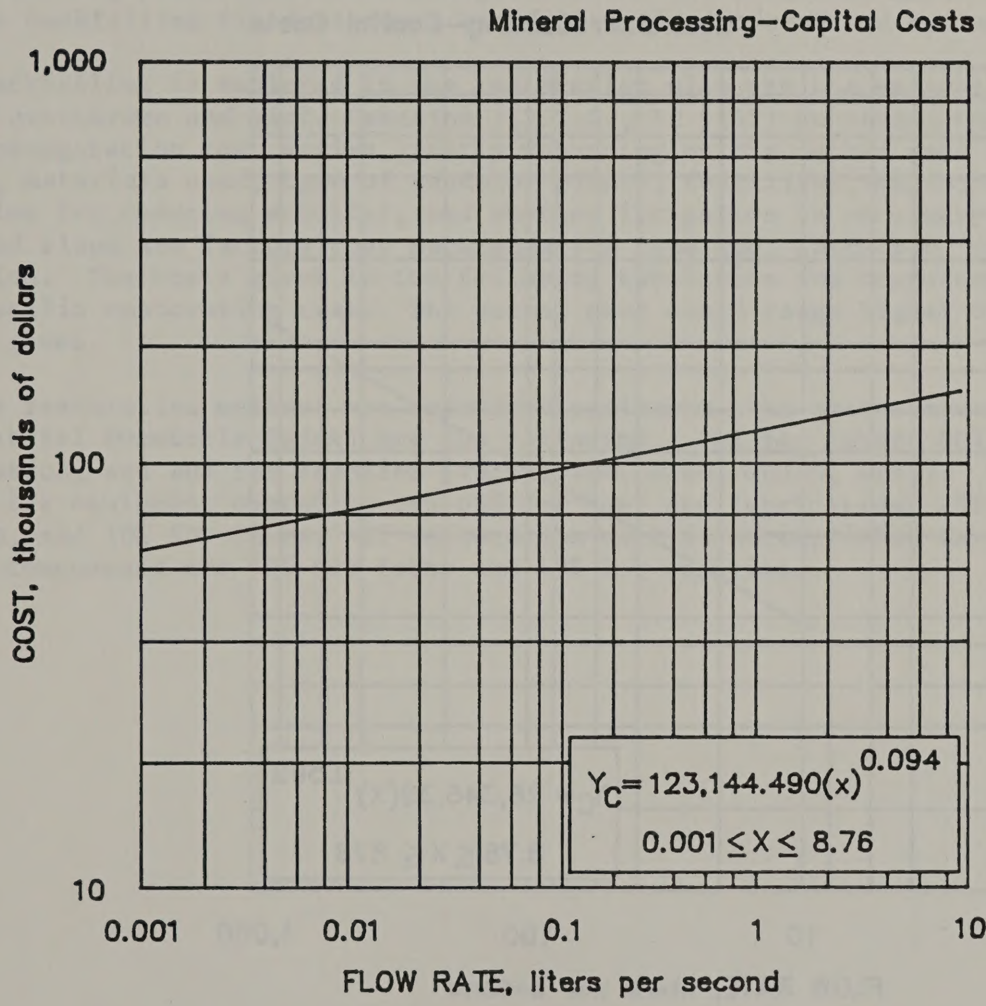
(E) <u>Purchased Equipment Cost</u> $(Y_{E\ 0.001-8.76\ L/s}) = 16{,}008.780(X)^{0.094}$

For waste water effluent rates between 8.76 to 876 L/s, the capital cost is (Y_C 8.76-876 L/s) = $26{,}346.39(X)^{0.562}$ and is distributed as follows:

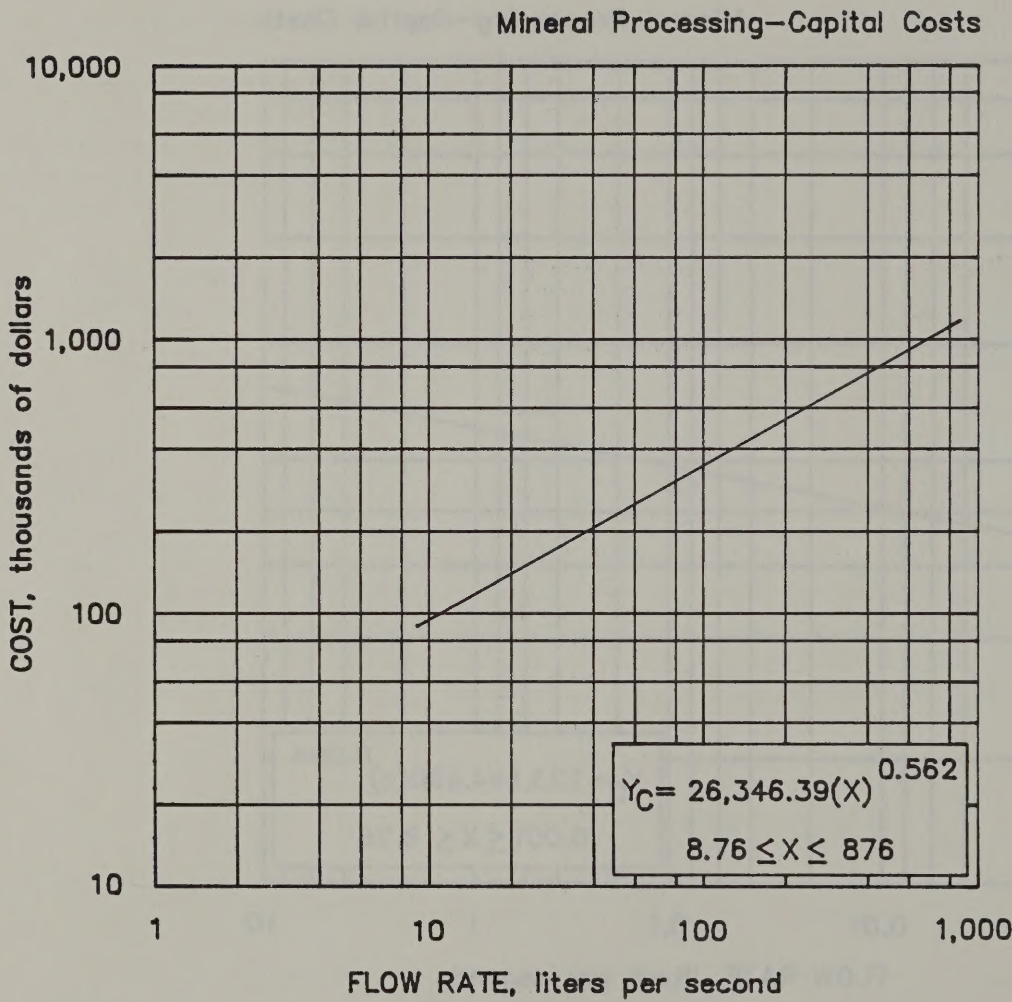
(L) <u>Construction Labor Cost</u> (Y_L 8.76-876 L/s) = $17{,}125.15(X)^{0.562}$

(S) <u>Construction Supply Cost</u> (Y_S 8.76-876 L/s) = $5{,}796.21(X)^{0.562}$

(E) <u>Purchased Equipment Cost</u> (Y_E 8.76-876 L/s) = $3{,}425.03(X)^{0.562}$



6.1.10.3.2.a Wastewater treatment
NEUTRALIZATION



6.1.10.3.2.b Wastewater treatment
NEUTRALIZATION

6.1.11. RESTORATION

Mine restoration is the process of initiating and accelerating the natural continuous trend toward recovery (stabilization) etc.), the type of environment (desert, flatland, grass lands, mountains, etc.), and the restoration requirements by law in any given State (which range from none to very strict). Some States require permits prior to disturbing the ground surface. Typically, the permit specifies that the area must be reclaimed, hectare for hectare, to a use similar to the prior use or other beneficial use. Most restoration activities for mines include regrading and leveling plant sites (and revegetation of the disturbed area) but do not include backfilling (in most cases backfilling is not required by law).

If backfilling is employed in the restoration plan use the excavation, load and haul overburden and waste (section 3.2.1.4., IC 9142) to obtain backfilling cost. The revegetation cost varies greatly depending on the method used (hand or machinery), materials used, type of seeds or plants, fertilizer, mulch, chemicals (such as lime for reducing acidity), and whether irrigation is necessary. Climate and ground slope are factors that determine the type and, therefore, the costs of restoration. The costs given in the following tabulation are representative costs for a specific restoration task. The actual cost could range higher or lower than the cost given.

Where restoration methods use motorized equipment, the cost components (from the Industrial Chemicals Index) are the following: 40% for labor, 40% for equipment operation, and 20% for supplies (fertilizer, seed, mulch, etc.). The cost components for equipment operation are 65% for fuel and lubrication, 25% for repair parts, and 10% for tires. If restoration work is accomplished manually, then the cost components are 60% for labor and 40% for supplies.

COST COMPARISONS OF RESTORATION METHODS

	Cost per hectare	Remarks
SPECIFIC RESTORATION WORK (INDEPENDENT OF CLIMATE OR GEOGRAPHY)		
Revegetation on steep slope—roadside slopes, tailing slopes, or waste dump slopes, using hydroseeder with fiber mulch.	$1,000-1,500	Based on using 18 kg/ha of seed, 73 kg/ha of fertilizer, and expenses to use a boom crane, pickup truck, 2 equipment operators, and a swamper.
Transplanting trees or shrubs by hand on moderate to steep slopes.	5,000	Assume 2,500 trees hand planted per hectare at $2 per tree or shrub.
Sand and gravel restoration, includes placers; leveling, grading, topsoiling, reseeding.	3,000	Based on a typical sand-and-gravel operation near Denver, CO.
Annual maintenance (fertilizers added for above).	160	Cost for applying fertilizer.
Restoration of borrow pit - backfilling leveling and reseeding.	400-600	None.
RESTORATION IN HIGH ALTITUDE (MOUNTAINOUS) TERRAIN		
Regrading and reseeding - not including topsoiling.	$4,000	Regrading for adequate drainage to minimize erosion, seedbed preparation, and reseeding (including transplanting trees and shrubs).
Maintenance (added to regrading cost cost).	130	Purchasing-applying fertilizer—application cost for 1 yr. If application is on area where at least 30-cm depth of topsoil has been added, only 1 year's application needed. If topsoil has not been added, then as many as 4 applications may be required over a 6- to 8-year period.
Topsoil removal not necessary for access to ore body—added to regrading cost (if necessary to remove topsoil to gain access to ore body, then only $1,300/ha of this cost would be attributed to restoration cost).	7,000	Using $2.30/m^3 cost of stockpiling soil to cover a disturbed area to a depth of 30 cm. Assume topsoil moved and emplaced once. If moved, then stored and moved again to final placement, cost could double).
RESTORATION IN ARID AND SEMIARID LANDS		
Soil added................................	$5,000	Required to achieve restoration on only the most severely disturbed sites. Generally serves to accelerate the rate of achieving permanent self-sustaining vegetation.

COST COMPARISONS OF RESTORATION METHODS—Continued

	Cost per hectare	Remarks
RESTORATION IN ARID AND SEMIARID LANDS—Continued		
Seeding and irrigation in arid climate on tailings dams, waste dump sites, road slopes.	\$12,000-15,000	Irrigation system cost (sprinkler or drip tube) is estimated at \$8,000/ha. Water assumed to be pumped on site at annual rate of 12,000 to 18,000 m^3/ha at \$63 to \$67 per 1,000 m^3 of water.
Seed and fertilizer broadcast on surface —no soil coverage or mulch.	700	Minimum slope where seed will cover naturally with soil. Seed broadcast manually.
Hydromulching with 680 kg wood fiber per hectare plus seed and fertilizer.	1,900-2,500	Most common southwestern U.S. hydromulch mix; will hold seed and fertilizer in place on steep and smooth slopes.
Straw or hay broadcast with straw blower on surface at 3,400 kg/ha.	2,500	Very effective as energy absorber and mulch. Not used on steep slopes. Cost increase significant if slopes over 14 m from access.

6.1. MINERAL PROCESSING--CAPITAL COSTS

6.1.12. ENGINEERING AND CONSTRUCTION MANAGEMENT FEES

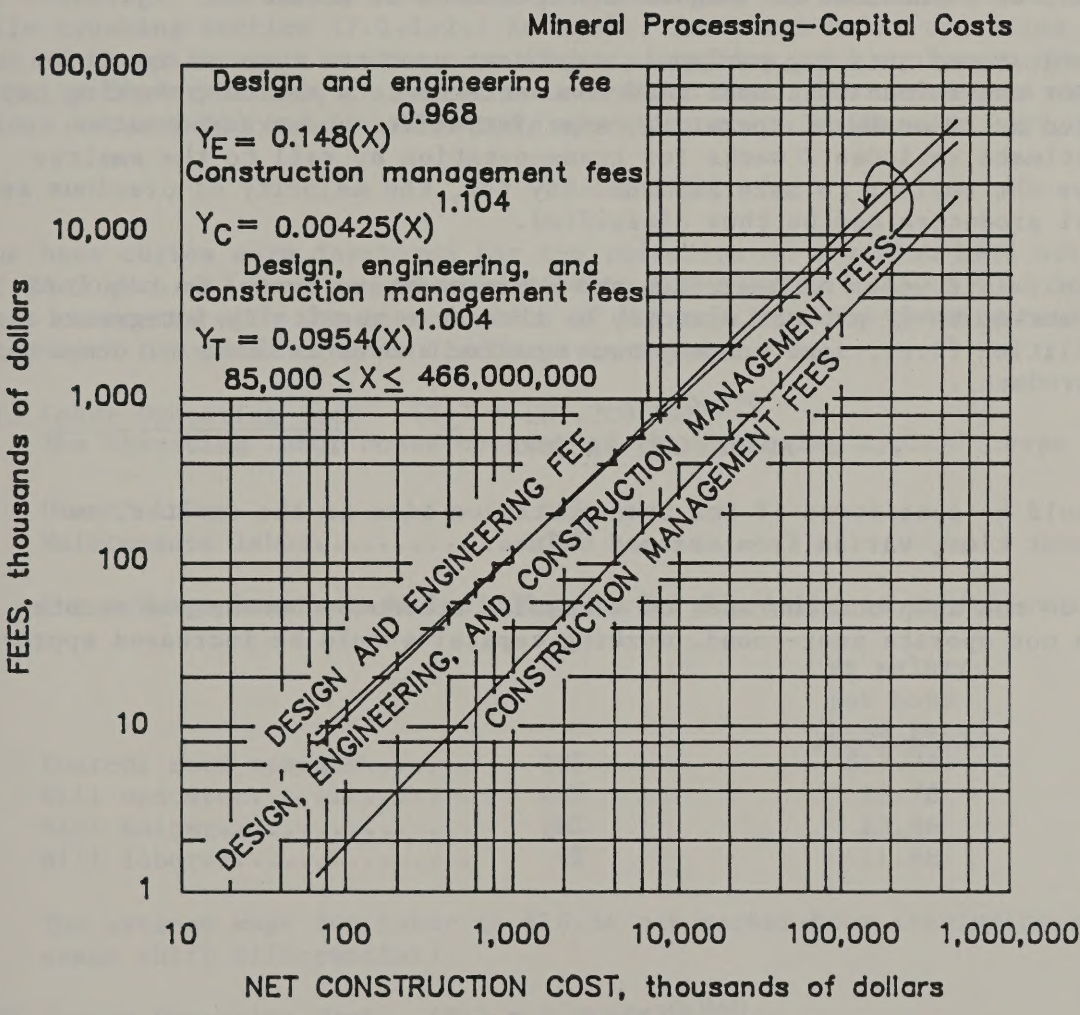
Engineering and construction management fees curves are based on the net constructed cost (X) for numerous projects of varying complexities. The net construction cost is the sum of the group cost for sections 6.1.1. and 6.1.2. (comminution), 6.1.3. (beneficiation), 6.1.4. (solid-liquid separation), 6.1.5. (hydrometallurgy), 6.1.6. (special applications), 6.1.7. (transportation), 6.1.8. (general operations), and 6.1.10. (infrastructure). The total engineering and construction management fee curve is based on a single firm performing both tasks. The other two curves are based on different firms performing each task. Factors for escalation, location, etc., should not be applied to any of the curves.

The equations for each of the individual curves are as follows:

The construction management fee cost is $(Y_C) = 0.00425(X)^{1.104}$

The design and engineering fee cost is $(Y_E) = 0.148(X)^{0.968}$

The total design, engineering, and construction management fee cost is $(Y_T) = 0.0954(X)^{1.004}$



6.1.12. Engineering and construction management fees

6.1.13. WORKING CAPITAL

Working capital is the cash required to sustain a mining and/or milling operation between mining the ore and receiving revenue from its sale. It is the capital required to meet out-of-pocket expenses, such as payroll, equipment operation, utilities, and administrative operating costs. In aggregate, these are the total operating costs for the operation during the designated time period. Because this time lag persists, i.e., monies received in payment for September's production are reinvested in material and supplies to produce ore in November or December, a continuing account must be maintained as long as the operation is active.

A reasonable estimate of this lag period is dependent upon the type of operation under study. For operations that must send concentrates to a smelter, working capital is estimated as 10 weeks of operating, administrative, and transportation costs. This estimate includes 2 weeks for transportation by rail to the smelter and 2 months for the smelter to make payment. By far, the majority of precious and nonferrous metal producers can be thus classified.

Less working capital (6 weeks of operating and administrative costs) is required for mines that market their product directly or that have vertically integrated processing facilities (i.e., same company owns smelter and/or refinery or company sells the end product).

ADJUSTMENT FACTORS

Adjustments should be considered if the transportation time to the smelter, or smelter settlement time, varies from assumed values.

For mills that do not ship concentrates on a regular schedule, because of remoteness, and/or do not operate year-round, working capital should be increased appropriately.

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.1. COMMINUTION

7.1.1.1. CRUSHING

This unit operation pertains to the reduction of run-of-mine ore to a size suitable for grinding and further beneficiation operations. The cost curves are applicable to crushing operations performed either in the mine or at a surface location. The curves include the costs associated with crushing, screening, and transfer of material and are valid for the primary, secondary, and, if necessary, tertiary stages of crushing. The curves are valid for secondary and tertiary crushing when the mobile crushing section (7.1.1.2.) is used. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a daily feed rate (X), in metric tons ore per day. The curves are valid for operations between 500 and 100,000 mtpd, operating three shifts per day.

BASE CURVE

The base curves were developed for the reduction of a medium hard ore (work index of 14.3 kW.h/mt) from run-of-mine size to 80% passing 1.27 cm (0.5 in). The process commences with the introduction of the ore into the primary crusher and terminates with the final crusher discharge conveyor.

(L) Labor Operating Cost $(Y_L) = 187.200(X)^{0.279}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	50%
Maintenance labor..........	50%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator......	28%	$17.23
Mill operator..............	46%	16.78
Mill helper................	20%	13.66
Mill laborer...............	6%	11.68

The average wage for labor is $16.54 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.315(X)^{0.840}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 1.093(X)^{0.775}$
The equipment operation curve consists of 96% for wear materials and repair parts and 4% for lubrication.

ADJUSTMENT FACTORS

Ore Hardness Factor The base curves are premised on an ore hardness of 14.3 kW.h/mt. To adjust for a different work index, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = (14.3/I)^{-0.279}$

Supply factor $(F_S) = (14.3/I)^{-0.840}$

Equipment operation factor $(F_E) = (14.3/I)^{-0.756}$
where I = new work index, in kilowatt hours per metric ton.

Product Size Factor The particle size of the crushed product is ultimately dependent on the discharge opening setting of the final crusher(s) in the series. To adjust for a crusher discharge setting other than 1.27 cm, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = (S/1.27)^{-0.432}$

Supply factor $(F_S) = (S/1.27)^{-0.736}$

Equipment operation factor $(F_E) = (S/1.27)^{-0.714}$
where S = new crusher discharge setting, in centimeters.

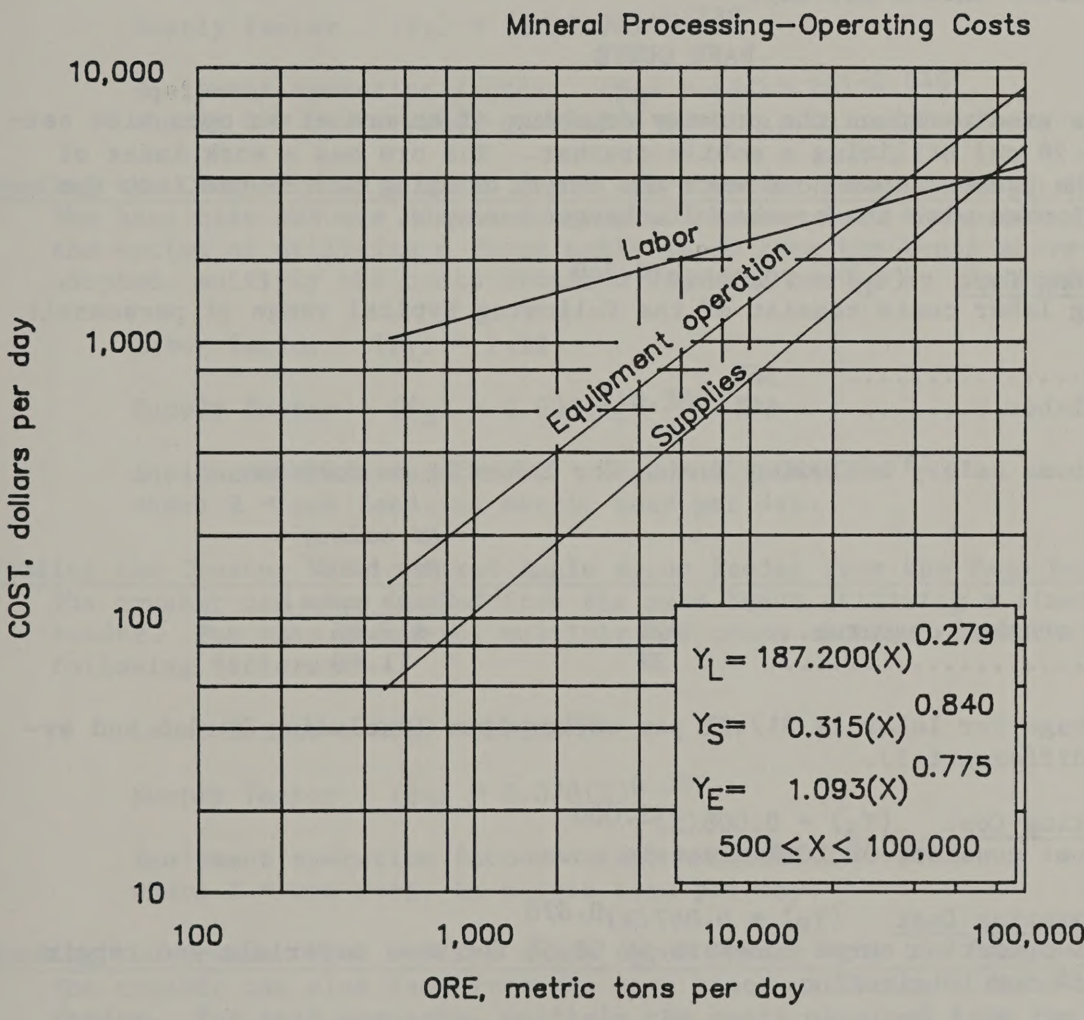
Mobile Crushing Factor In the event that mobile crushers are to be used as the primary crushers, multiply the costs obtained from the curves by the following factors to determine the costs of secondary and tertiary crushing:

Labor factor $(F_L) = 0.776$

Supply factor $(F_S) = 0.764$

Equipment operation factor $(F_E) = 0.676$

Long Distance Conveyors The base curves are predicated on the assumption that the primary crusher(s) are reasonably proximate to the fine crushing facility. If the distance between primary and secondary crushing facilities exceeds 150 m, a long-distance conveyor should be included in the cost estimate (see section 7.1.7.5.).



7.1.1.1. Crushing

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.1. COMMINUTION

7.1.1.2. MOBILE CRUSHING

The operating costs for mobile crushing are given on a metric ton per day basis. The costs include the operation of primary crusher, discharge conveyor, and feed hopper. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a production rate (X), in metric tons of ore per day. The curves are valid for operations between 17,600 and 79,000 mtpd, operating three shifts per day.

BASE CURVE

The base curve is predicated on the primary crushing of an ore at an open side setting of 7 in (17.78 cm) utilizing a mobile crusher. The ore has a work index of 14.3 kW.h/mt. The process commences with the direct dumping of the ore into the crusher and terminates with the crusher discharge conveyor.

(L) Labor Operating Cost $(Y_L) = 79.988(X)^{0.248}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	36%
Maintenance labor..........	64%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room crusher operator...	97%	$17.56
Mill laborer....................	3%	11.68

The average wage for labor is $17.21 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.008(X)^{1.000}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.087(X)^{0.878}$
The equipment operation curve consists of 95.5% for wear materials and repair parts and 4.5% for lubrication.

ADJUSTMENT FACTORS

Ore Hardness Factor The base curves are premised on an ore hardness of 14.3 kW.h/mt. To adjust for a different work index, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.993(14.300/I)^{-0.251}$

Supply factor $(F_S) = 1.004(14.300/I)^{-0.244}$

Equipment operation factor $(F_E) = 1.002(14.300/I)^{-0.878}$
where: I = new work index, in kilowatt hours per metric ton.

Crusher Open-Side Setting Factor The base curves are premised on an open-side setting of 17.78 cm. To adjust for a different crusher open-side setting, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = (S/17.78)^{-0.174}$

Supply factor $(F_S) = (S/17.78)^{-0.230}$

Equipment operation factor $(F_E) = (S/17.78)^{-0.646}$
where: S = new crusher open-side setting, in centimeters.

Feeding the Crusher With a Fixed Angle Apron Feeder From the Bench Above Factor The base case assumes direct dumping of the ore into the primary crusher. If the option of utilizing a fixed angle apron from the bench above the crusher is adopted, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.22$

Supply factor $(F_S) = 0.003(X)^{0.583}$

Equipment operation factor $(F_E) = 0.0004(X)^{0.762}$
where X = ore feed, in metric tons per day.

Feeding the Crusher With a Fixed Angle Apron Feeder From the Same Bench Factor The crusher can also be fed from the same bench utilizing a fixed angle apron feeder. For this scenario, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.22$

Supply factor $(F_S) = 0.078(X)^{0.287}$

Equipment operation factor $(F_E) = 0.0004(X)^{0.762}$
where X = ore feed, in metric tons per day.

Feeding the Crusher With a Fixed Angle Apron Feeder From the Same Bench Factor The crusher can also feed from the same bench utilizing a fixed angle apron feeder. For this scenario, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.22$

Supply factor $(F_S) = 0.078(X)^{0.287}$

Equipment operation factor $(F_E) = 0.0004(X)^{0.762}$
where X = ore feed, in metric tons per day.

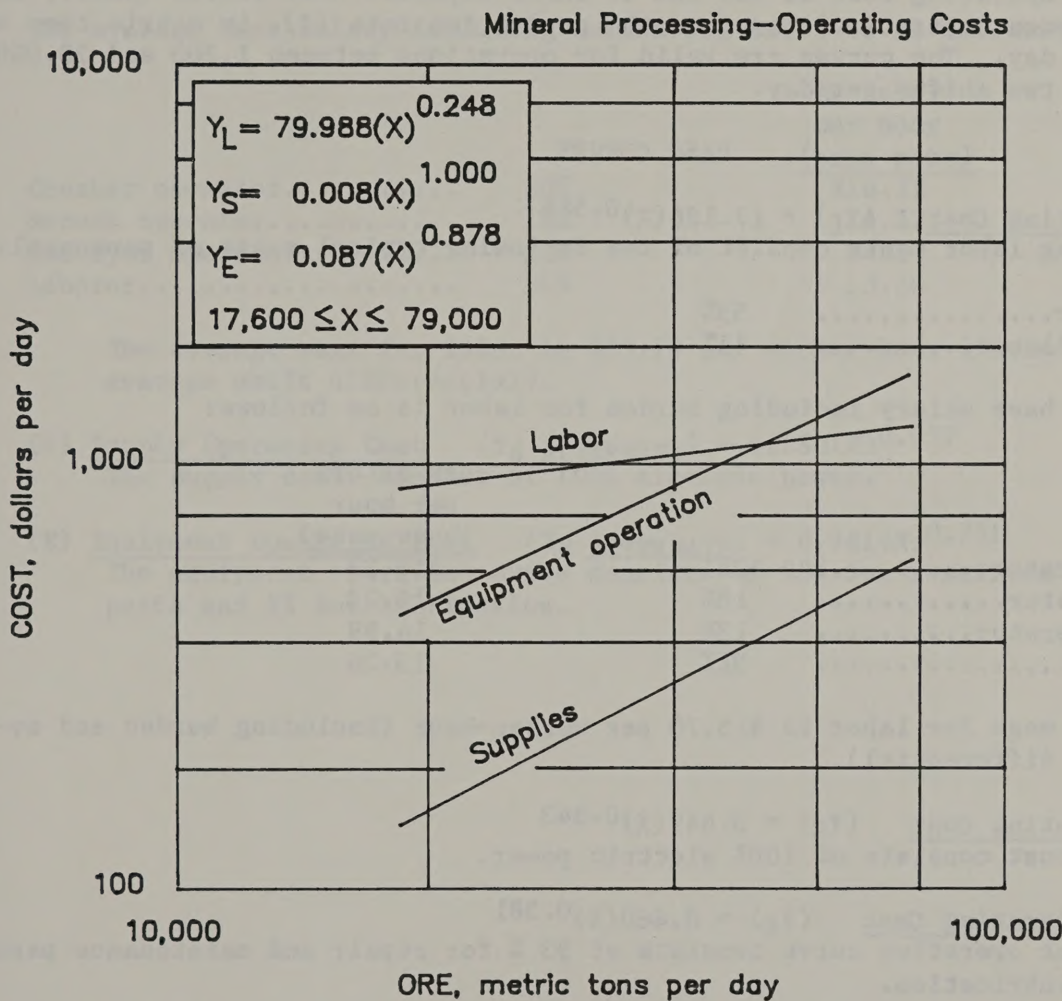
Feeding the Crusher With a Variable Angle Apron Feeder From Same Bench Factor
The most operating flexibility is obtained by feeding the crusher with an apron feeder that is capable of adjusting to different ground elevations. For this case, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.35$

Supply factor $(F_S) = 2.06$

Equipment operation factor $(F_E) = 0.0004(X)^{0.762}$
where X = ore feed, in metric tons per day.

Shift Factor The curve is based on a three-shift-per-day operation. The mobile crusher can also be operated one or two shifts per day. For a reduced shift operation, decrease the operating costs proportionately.



7.1.1.2. Mobile crushing

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.1. COMMINUTION

7.1.1.3. IMPACT CRUSHING

Impact crushing operating costs, as determined in this section, are based on metric tons of mine run ore reduced by impactors to a size suitable for further beneficiation. The costs are applicable for reduction of mine run ore, with an equivalent hardness and abrasiveness of medium hard limestone, to minus 0.95 cm (3/8 in).

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the production rate (X), in metric tons of ore crushed per day. The curves are valid for operations between 1,200 and 20,000 mtpd, operating two shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 17.126(X)^{0.585}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	55%
Maintenance labor..........	45%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Crusher operator...........	38%	$16.22
Screen operator............	18%	16.22
Conveyor operator..........	13%	14.89
Laborer....................	31%	13.26

The average wage for labor is $15.70 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.649(X)^{0.843}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 8.460(X)^{0.581}$
The equipment operation curve consists of 93 % for repair and maintenance parts and 7% for lubrication.

ADJUSTMENT FACTORS

Shift-Feed Rate Factor Because of high maintenance requirements, impact crushers are limited to not more than two shifts per day. If the crushing facility operates one shift per day, multiply the daily feed rate by two, then obtain a cost using the adjusted daily feed rate, then decrease this cost by 50% to arrive at the proper operating cost.

Alternative Impact Crushing If other than primary impact crushing facilities are required (see section 6.1.1.3., impact crushing capital cost), then use the following equations, based on the production rate (X), in metric tons of ore per day. The curves are valid for operations between 1,200 and 20,000 mt, operating two shifts per day.

(L) Labor Operating Cost $(Y_{L\ ALTERNATE}) = 7.884(X)^{0.607}$
The operating labor costs consist of the following typical range of personnel:

Direct labor..........	72%
Maintenance labor.....	28%

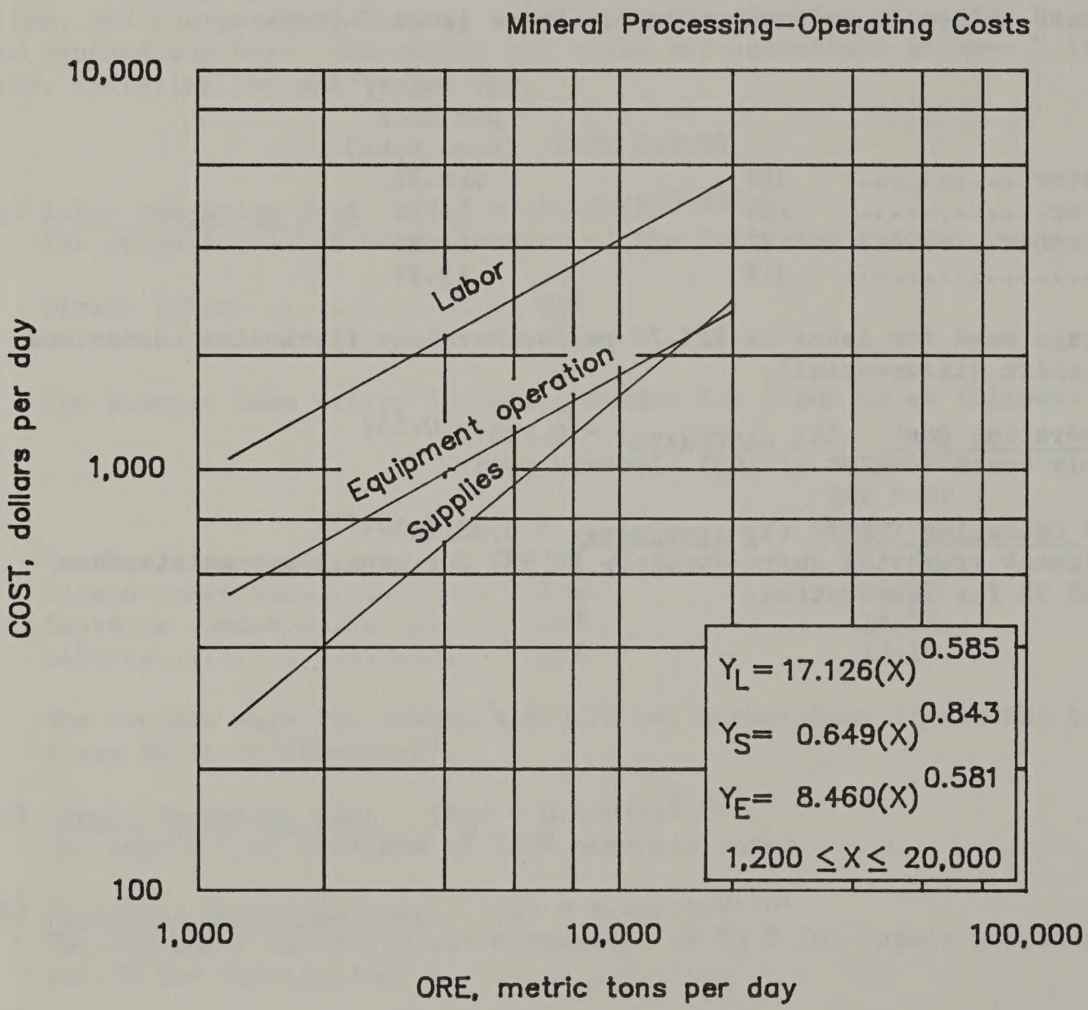
The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Crusher operator...........	38%	$16.22
Screen operator............	18%	16.22
Conveyor operator..........	13%	14.89
Laborer....................	31%	13.26

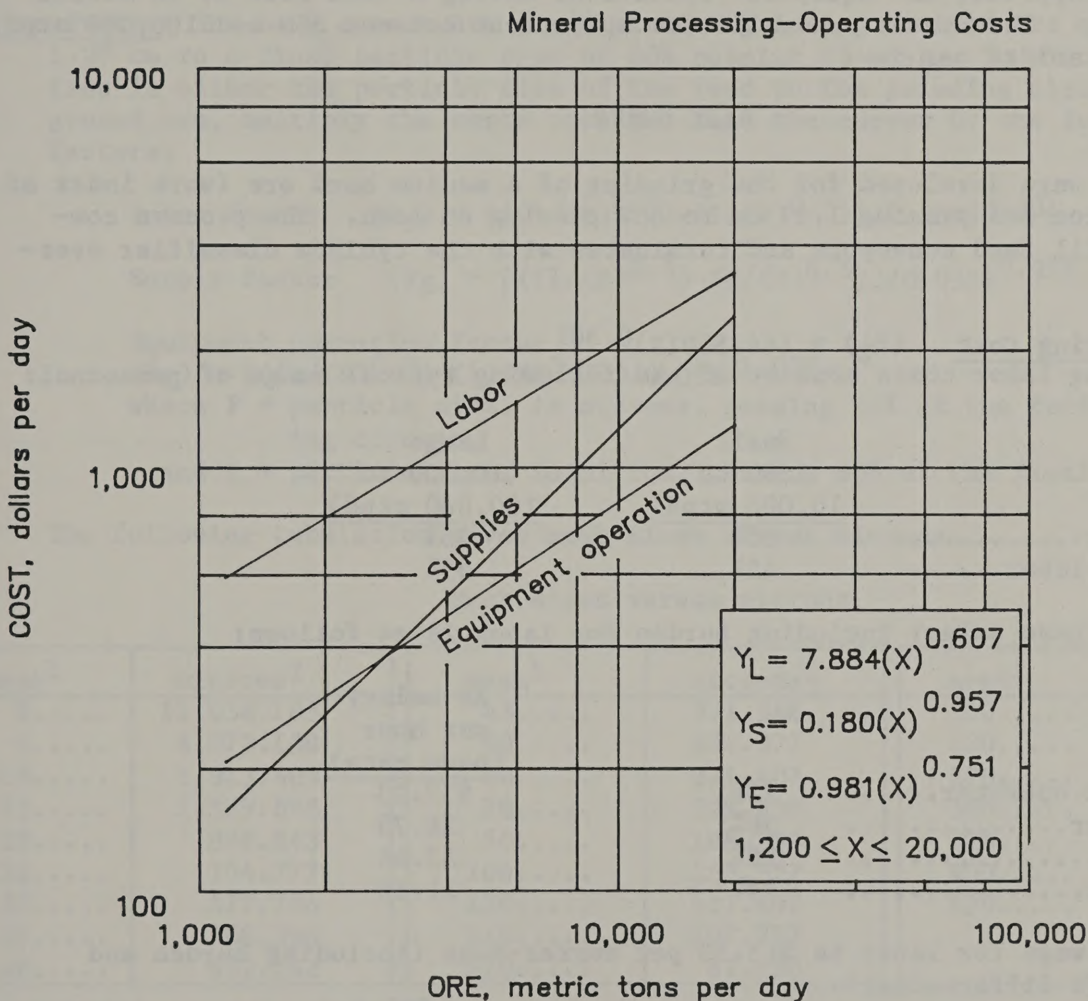
The average wage for labor is $15.70 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_{S\ ALTERNATE}) = 0.180(X)^{0.957}$
The supply costs consist of 100% electric power.

(E) Equipment Operating Cost $(Y_{E\ ALTERNATE}) = 0.981(X)^{0.751}$
The equipment operation curve consists of 93% for repair and maintenance parts and 7% for lubrication.



7.1.1.3.a Impact crushing



7.1.1.3.b Alternative impact crushing

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.2. COMMINUTION

7.1.2.1. GRINDING

This unit operation pertains to the wet grinding of crushed ore to a size suitable for further beneficiation operations. The curves are based on closed circuit operation with the mills running at normal load and percentage of critical speed and include the costs associated with grinding, classification, and pumping of the resultant slurry. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate X, in metric tons ore per day. The curves are valid for operations between 380 and 100,000 mtpd, operating three shifts per day.

BASE CURVE

The base curves were developed for the grinding of a medium hard ore (work index of 14.3 kW.h/mt) from 80% passing 1.27 cm to 80% passing 65 mesh. The process commences at the mill feed conveyors and terminates with the cyclone classifier overflow.

(L) Labor Operating Cost $(Y_L) = 144.500(X)^{0.301}$
The operating labor costs consist of the following typical range of personnel:

	Small (380 to 10,000 mtpd)	Large (10,000 to 100,000 mtpd)
Direct labor...........	55%	45%
Maintenance labor.......	45%	55%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator......	23%	$17.23
Mill operator..............	36%	16.78
Mill helper................	18%	13.66
Mill laborer...............	23%	11.68

The average wage for labor is $15.33 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.689(X)^{0.977}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.308(X)^{1.000}$
The equipment operation curve consists of 96% for wear materials and repair parts and 4% for lubrication.

ADJUSTMENT FACTORS

Ore Hardness Factor The base curves are premised on an ore hardness of 14.3 kW.h/mt. To adjust for a different work index, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = (14.3/I)^{-0.301}$

Supply factor $(F_S) = (14.3/I)^{-0.977}$

Equipment operation factor $(F_E) = (14.3/I)^{-1.000}$
where I = new work index, in kilowatt hours per metric ton.

Size Factor The base curves are predicated on grinding crushed ore of 80% passing 1.27 cm to a final particle size of 80% passing 65 mesh. To allow for variation in either the particle size of the feed to the grinding circuit or of the ground ore, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = [((1/(P)^{0.5})-(1/(F)^{0.5}))/0.055]^{0.301}$

Supply factor $(F_S) = [((1/(P)^{0.5})-(1/(F)^{0.5}))/0.055]^{0.977}$

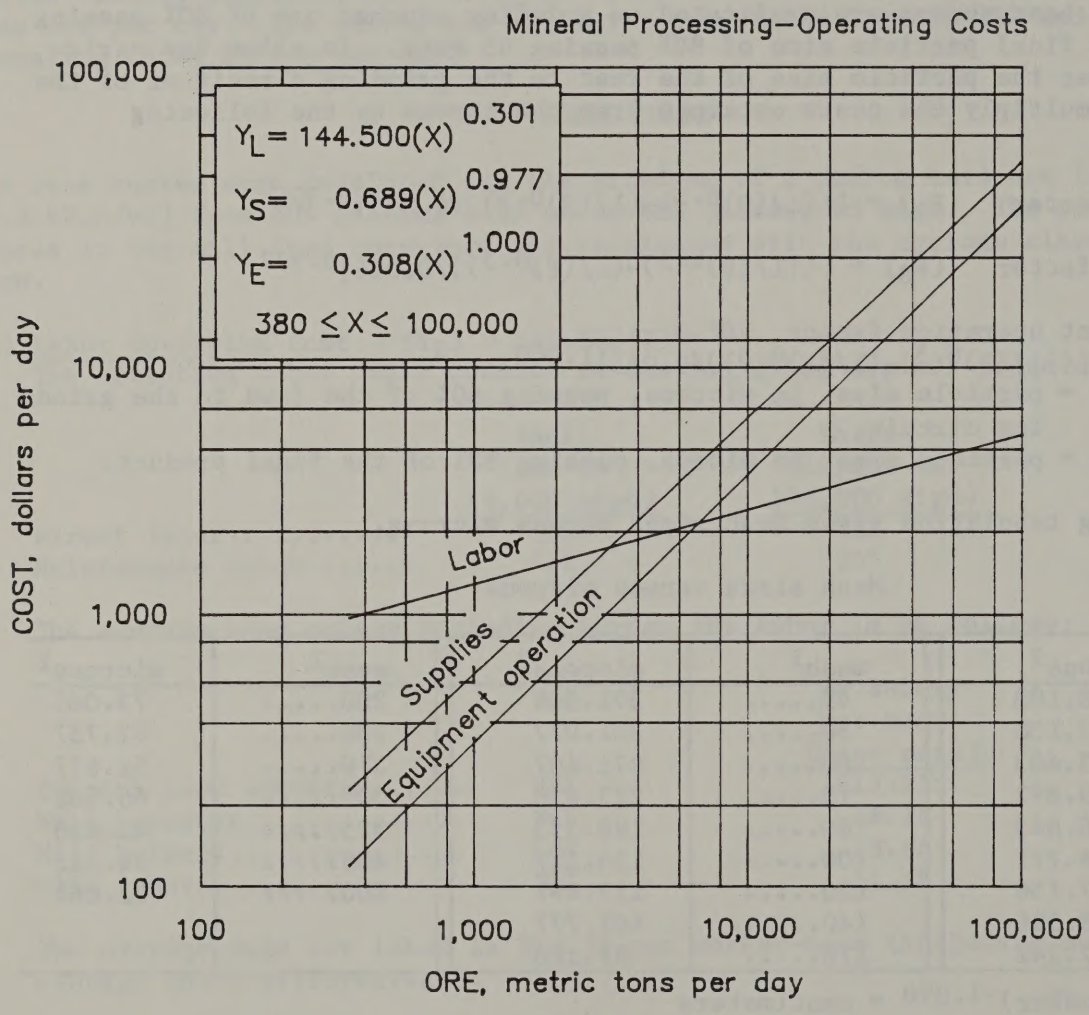
Equipment operation factor
$(F_E) = [((1/(P)^{0.5})-(1/(F)^{0.5}))/0.055]^{1.000}$
where F = particle size, in microns, passing 80% of the feed to the grinding circuit,
and P = particle size, in micron, passing 80% of the final product.

The following tabulation gives mesh sizes versus microns.

Mesh sizes versus microns

mesh[1]	microns[2]	mesh[1]	microns[2]	mesh[1]	microns[2]
2.....	11,058.183	45.....	371.368	200.....	73.061
5.....	4,073.138	50.....	331.077	230.....	62.737
10.....	1,913.403	60.....	271.407	270.....	52.677
15.....	1,229.892	70.....	229.430	300.....	46.961
20.....	898.843	80.....	198.353	325.....	43.038
25.....	704.777	100.....	155.527	400.....	34.321
30.....	577.756	120.....	127.497	600.....	22.061
35.....	488.396	140.....	107.777		
40.....	422.242	170.....	87.220		

[1] $2.354 \times (\text{mesh number})^{-1.090}$ = centimeters
[2] Centimeters X 10,000 = microns



7.1.2.1. Grinding

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.2. COMMINUTION

7.1.2.2. SEMIAUTOGENOUS GRINDING

The costs for semiautogenous grinding (SAG) are given on a metric ton per day basis. The costs include the operation of grinding mills, conveyors, pumps and classifier. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on feed rate (X), in metric tons of ore per day. The curves are valid for operations between 330 and 111,800 mtpd, operating one shift per day.

BASE CURVES

The base curves are for SAG mill grinding of sulfide ores.

(L) Labor Operating Cost $(Y_L) = 116.035(X)^{0.304}$

The operating labor costs consist of the following typical range of personnel:

	Small (330 to 40,000 mtpd)	Large (40,000 to 111,800 mtpd)
Direct labor...............	55%	45%
Maintenance labor..........	45%	55%

The average base salary including burden for labor is as follows:

	Small (330 to 40,000 mtpd)	Large (40,000 to 111,800 mtpd)	Av salary per hour (base rate)
Control room operator......	33%	23%	$17.23
Mill operator..............	24%	23%	16.78
Mill suboperator...........	-	20%	14.56
Mill helper................	33%	11%	13.66
Mill laborer...............	10%	23%	11.68

The average wage for labor is $15.13 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.614(X)^{0.986}$

The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.312(X)^{0.998}$

The equipment operation curve consists of 94% for wear materials (balls and liner) and 6% for repair parts.

ADJUSTMENT FACTORS

Single-Stage SAG Grinding Factor The operating cost curves must be adjusted for single-stage grinding. Multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.33$

Supply factor $(F_S) = 1.95$

Equipment operation factor $(F_E) = 1.07$

Uranium Factor The operating cost curves must be adjusted for uranium grinding. Multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 3.709(X)^{-0.201}$

Supply factor $(F_S) = 0.704(X)^{-0.102}$

Equipment operation factor $(F_E) = 0.088(X)^{0.214}$
where X = uranium ore ground, in metric tons per day.

Single-Stage (Sulfide) Autogenous Grinding Factor The operating cost curves must be adjusted for single-stage (sulfide) autogenous grinding. Multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.911$

Supply factor $(F_S) = 1.0$

Equipment operation factor $(F_E) = 4.0$

Iron Ore-SAG Factor For the grinding of taconite in a two-stage circuit, where the primary mill is a SAG mill, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.093$

Supply factor $(F_S) = 1.626$

Equipment operation factor $(F_E) = 4.473$

Hardness Factor The other operating cost curves can be adjusted by multiplying the base costs by the following factor:

Hardness factor $(F_H) = (N)/14.0$
where N = new power requirements, in horsepower hour per metric ton.

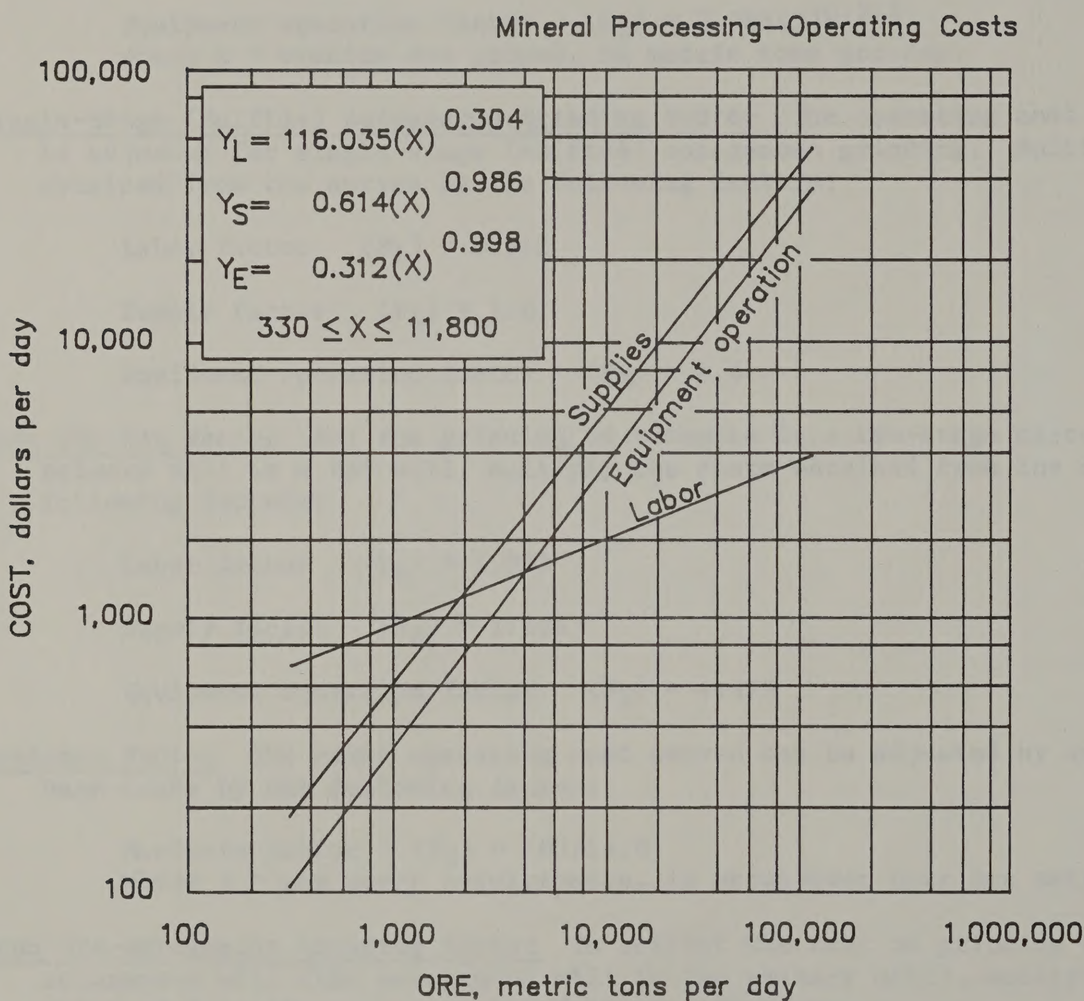
Iron Ore-Autogenous Grinding Factor To reflect the cost of grinding taconite in an autogenous mill (the autogenous mill is the primary mill), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.352$

Supply factor $(F_S) = 2.086$

Equipment operation factor $(F_E) = 3.925$

Shift Factor The curve is based on a one-shift-per-day operation. Typically, semi-autogenous circuits are operated primarily on day shift only. For a two or three-shift operation, increase the operating costs proportionately.



7.1.2.2. Semiautogenous grinding

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.2. COMMINUTION

7.1.2.3. RAYMOND MILL GRINDING

The operating cost curves cover costs associated with dry grinding barite to 90% minus 325 mesh. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on feed rate (X), in metric tons of ore per day. The curves are valid for operations between 115 and 1,290 mtpd, operating two shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 20.073(X)^{0.570}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	42%
Maintenance labor..........	58%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Mill operator..............	95%	$17.11
Mill laborer...............	5%	13.66

The average wage for labor is $16.92 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.001(X)^{0.952}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 1.999(X)^{0.800}$
The equipment operation curve consists of 100% for repair parts and materials.

ADJUSTMENT FACTORS

Ore Hardness Factor The base curves are premised on an ore hardness of 12.2 hp.h/mt. To adjust for a different work index, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = (12.2/I)^{-0.501}$

Supply factor $(F_S) = (12.2/I)^{-0.800}$

Equipment operation factor $(F_E) = (12.2/I)^{-0.952}$
where I = new work index, in horsepower hours per metric ton.

<u>Flash Drying Factor</u> If the barite is dried prior to grinding, the supply curve must be adjusted for natural gas consumed. Multiply the supply operating cost obtained from the curve by the following factor:

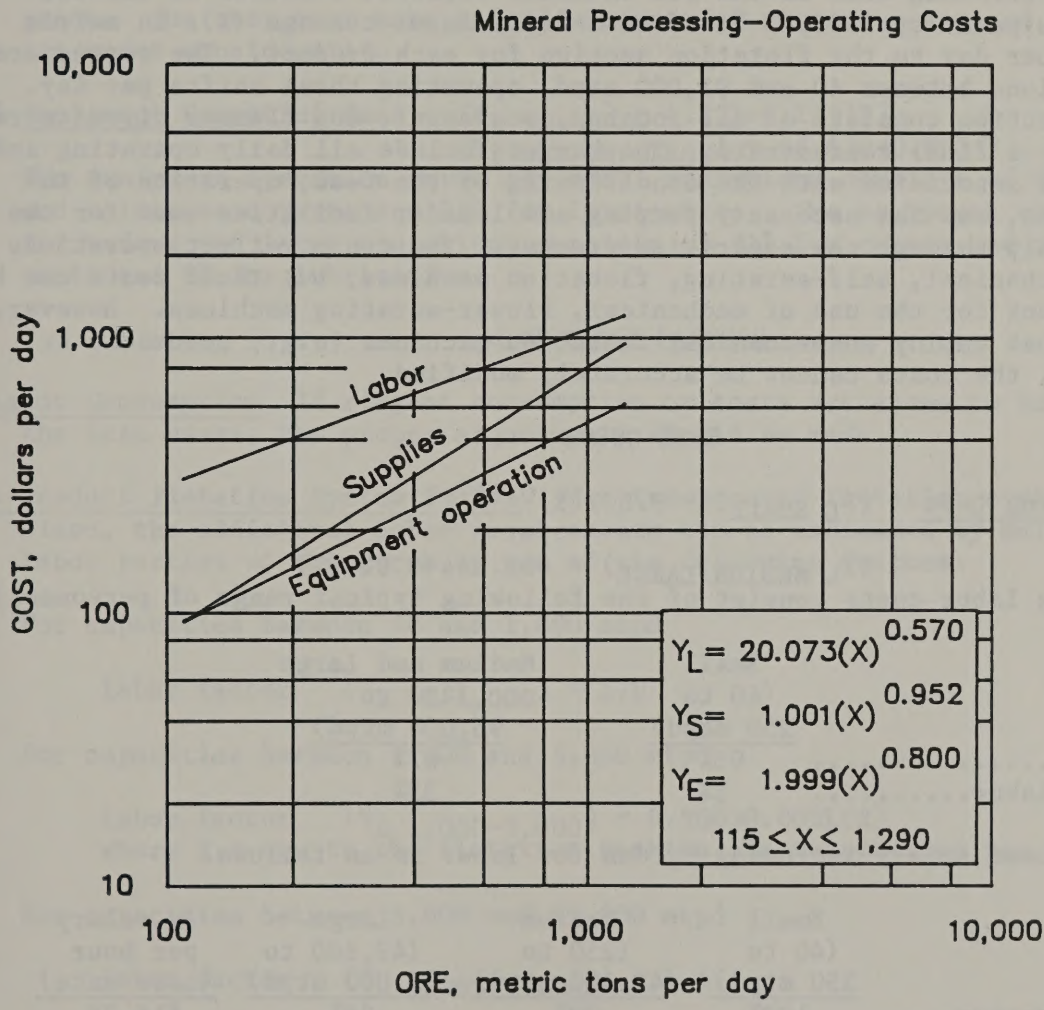
Supply factor $(F_S) = 13.32$

<u>Potash Factor</u> The operating cost curves must be adjusted for grinding langbeinite. Multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.74$

Supply factor $(F_S) = 1.3$

Equipment operation factor $(F_E) = 0.38$



7.1.2.3. Raymond mill grinding

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.3. BENEFICIATION

7.1.3.1. FLOTATION

The cost curves in this section are based on flotation operations that produce a single concentrate product. Nevertheless, for operations that produce multiple concentrate products, costs can be estimated by reapplying the curves for each product, making the appropriate input tonnage reduction before each reapplication.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a daily input tonnage (X), in metric tons of dry ore per day to the flotation section for each product. The curves are valid for operations between 40 and 95,000 mtpd, operating three shifts per day. Each flotation section consists of all rougher, scavenger, and cleaner circuits required to produce a final concentrate. The curves include all daily operating and maintenance costs associated with the conditioning of the feed, operation of the flotation machines, and the necessary pumping and launder facilities used for the passage of the pulp through the separation process. The costs reflect operations that use only mechanical, self-aerating, flotation machines, but these costs can be adjusted to account for the use of mechanical, blower-aerating machines. However, for operations that employ nonmechanical flotation machines (e.g., pneumatic or column machines), the costs cannot be accurately modified.

BASE CURVE

(L) Labor Operating Cost $(Y_{L\ SMALL}) = 9.807(X)^{0.757}$

$(Y_{L\ MEDIUM/LARGE}) = 483.344+0.026(X)$

The operating labor costs consist of the following typical range of personnel:

	Small (40 to 250 mtpd)	Medium and Large (250 to 95,000 mtpd)
Direct labor...............	95%	67%
Maintenance labor..........	5%	33%

The average base salary including burden for labor is as follows:

	Small (40 to 250 mtpd)	Medium (250 to 47,600 mtpd)	Large (47,600 to 95,000 mtpd)	Av salary per hour (base rate)
Flotation operator.....	100%	90%	25%	$16.78
Assistant flotation operator.............	-	-	21%	14.56
Reagent monitor........	-	-	20%	13.66
Plant laborer..........	-	10%	34%	11.68

The average wage for labor is $14.44 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.832(X)^{1.000}$
The supply curve consists of 82% reagents and 18% electric power.

The reagents usage consists of

	Usage (lb/mt)	Deliverable Cost ($/lb)
Slaked Lime (Calcium Hydroxide)...............	5.500	0.061
MIBC (Methyl Isobutyl Carbinol)...............	0.075	0.580
Aero 343 (Sodium Isopropyl Xanthate)..........	0.100	0.840
Sodium Sulfhydrate (Sodium Hydrosulfide)......	0.750	0.750

The reagent usage is based on a copper ore of average floatability and economic grade. The user must make any adjustments of reagent usage and costs for the ore under consideration.

(E) Equipment Operating Cost $(Y_{E\ SMALL}) = 4.131+0.149(X)$
$(Y_{E\ MEDIUM/LARGE}) = 66.630+0.013(X)$
The equipment operation curve for small operations consists of 81% for repair and maintenance parts and 19% for lubrication. The equipment operation curve for medium and large operations consists of 91% for repair and maintenance parts and 9% for lubrication.

ADJUSTMENT FACTORS

Reagent Consumption If reagent consumption or costs are known to be different from the base usage, the proper adjustments should be made.

Two-Product Flotation System Factor If a two-product flotation system is to be utilized, the additional labor requirements can be estimated by multiplying the labor portion of the curve by one of the following factors:

For capacities between 40 and 1,000 mtpd

Labor factor $(Y_{L\ 40-1,000}) = 1.0$

For capacities between 1,000 and 5,000 mtpd

Labor factor $(Y_{L\ 1,000-5,000}) = 0.900+0.0001(X)$
where X = ore to the flotation section, in metric tons per day.

For capacities between 5,000 and 95,000 mtpd

Labor factor $(Y_{L\ 5,000-95,000}) = 1.4$

Three-Product Flotation System Factor If a three-product flotation system is to be utilized, the additional labor requirements can be estimated by multiplying the labor portion of the curve by one of the following factors:

For capacities between 40 and 1,000 mtpd

Labor factor $(Y_{L\ 40\text{-}1,000}) = 1.0$

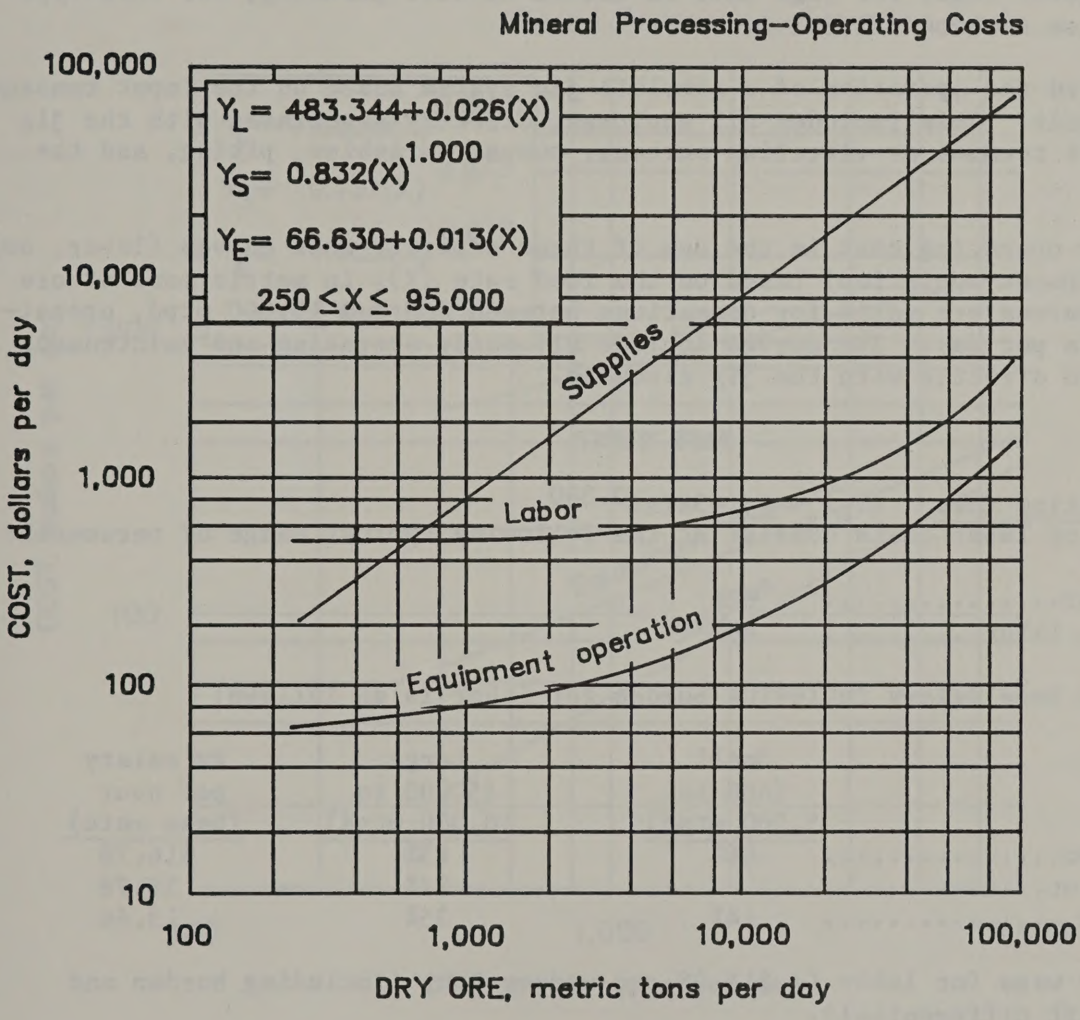
For capacities between 1,000 and 5,000 mtpd

Labor factor $(Y_{L\ 1,000\text{-}5,000}) = 0.837+0.000163(X)$
where X = ore to the flotation section, in metric tons per day.

For capacities between 5,000 and 95,000 mtpd

Labor factor $(Y_{L\ 5,000\text{-}95,000}) = 1.652$

External Blower System If the flotation machines require an external blower system for pulp aeration, the extra operating costs (labor, electric power, overhaul and repair parts, and lubrication) should be added to the applicable base curve costs.



7.1.3.1. Flotation

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.3. BENEFICIATION

7.1.3.2.1. GRAVITY SEPARATION
JIGS

The equations of this section can be used to estimate jig operating costs for the separation of heavy-ore minerals from waste. The equations are most applicable to barite, gold placer, diamond, and chromite processing operations. The base curves are not applicable to dredge operations; see section 3.2.2.4, (IC 9142). Also, the curves do not cover costs for jigs used in closed-circuit grinding; for this type of operation, use section 7.1.3.2.2.

Costs are derived for operation of a complete jig system based on the input tonnage to the jig circuit. This includes all equipment directly associated with the jig circuit, such as trommel or vibrating screens, pumps, surgebins, piping, and the jig units.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the feed rate (X), in metric tons of ore per day. The curves are valid for operations between 400 and 10,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated directly with the jig circuits.

BASE CURVE

(L) <u>Labor Operating Cost</u> $(Y_L) = 76.038(X)^{0.340}$
The operating labor costs consist of the following typical range of personnel:

Direct labor..............	60%
Maintenance labor..........	40%

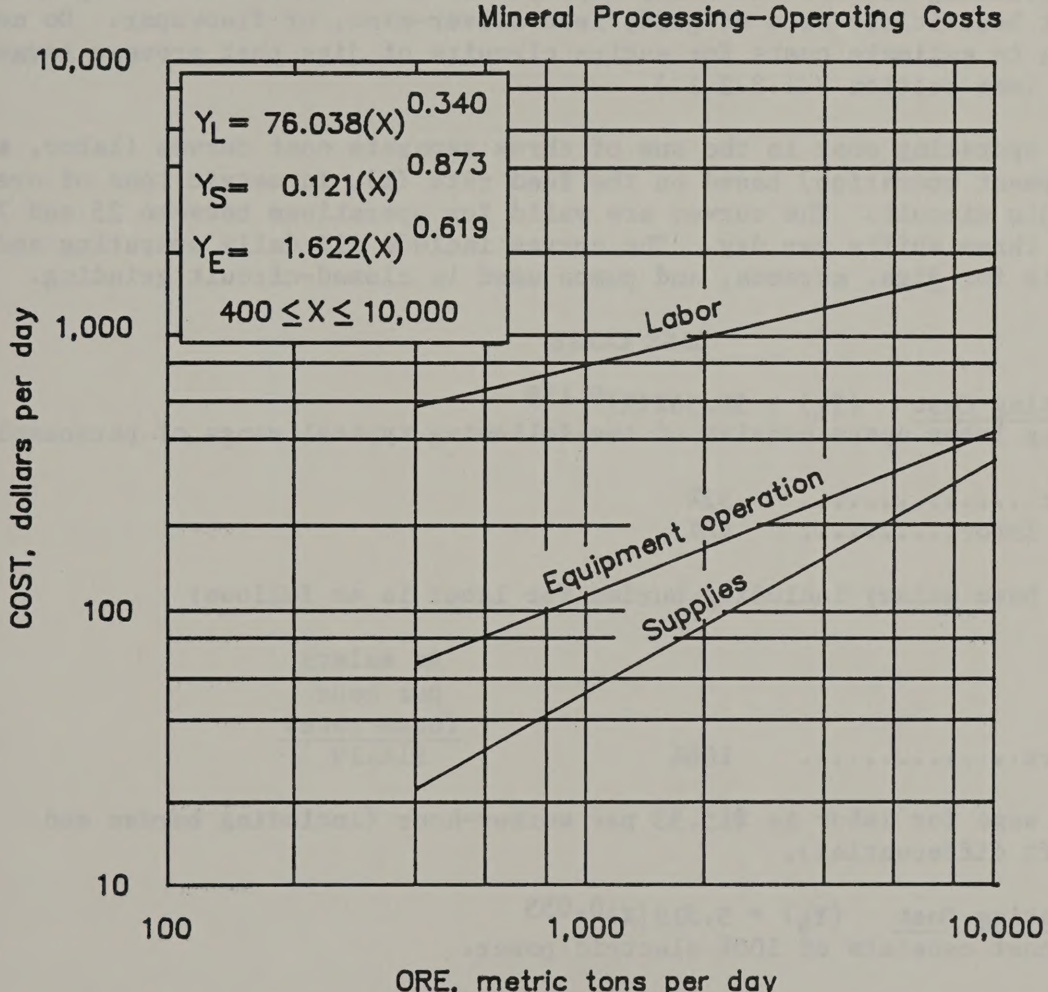
The average base salary including burden for labor is as follows:

	Small (400 to 5,000 mtpd)	Large (5,000 to 10,000 mtpd)	Av salary per hour (base rate)
Jig operator..............	86%	43%	$16.78
Mill operator.............	-	22%	16.78
Mill helper...............	14%	35%	13.66

The average wage for labor is $15.88 per worker-hour (including burden and average shift differential).

(S) <u>Supply Operating Cost</u> $(Y_S) = 0.121(X)^{0.873}$
The supply cost consists of 98% electric power and 2% lubricants.

(E) <u>Equipment Operating Cost</u> $(Y_E) = 1.622(X)^{0.619}$
The equipment operation curve consists of 98% for repair parts and 2% for lubrication. The curve includes allowances for the replacement of motors, screen cloths, hoses, and repair parts for pumps, jigs, and all other pieces of equipment directly associated with the jig circuits.



7.1.3.2.1. Gravity separation
JIGS

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.3. BENEFICIATION

7.1.3.2.2. GRAVITY SEPARATION JIGS IN CLOSED-CIRCUIT GRINDING

These curves cover the costs of using one jig to recover small amounts of unusually coarse or fine-free minerals from the grinding mill discharge. This is an accessory process used prior to other forms of treatment, such as flotation or cyanidation, where coarse material or large particles would not be recovered. Jigs in closed-circuit grinding are most commonly employed in small flotation and cyanidation plants that beneficiate ores of gold, lead-silver-zinc, or fluorspar. Do not use this section to estimate costs for entire circuits of jigs that process large tonnages of ore (see section 7.1.3.2.1.).

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the feed rate (X), in metric tons of ore per day to the jig circuit. The curves are valid for operations between 25 and 700 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs for jigs, screens, and pumps used in closed-circuit grinding.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 56.562(X)^{0.158}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	52%
Maintenance labor..........	48%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Mill laborers..............	100%	$14.19

The average wage for labor is $15.33 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 5.319(X)^{0.055}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 35.529e^{0.0002(X)}$
The equipment operation curve consists of 94% for repair parts and 6% for lubrication. The curve includes allowances for the replacement of motors, screen cloths, and repair parts for pumps, jigs, and all other pieces of equipment directly associated with this type of system.

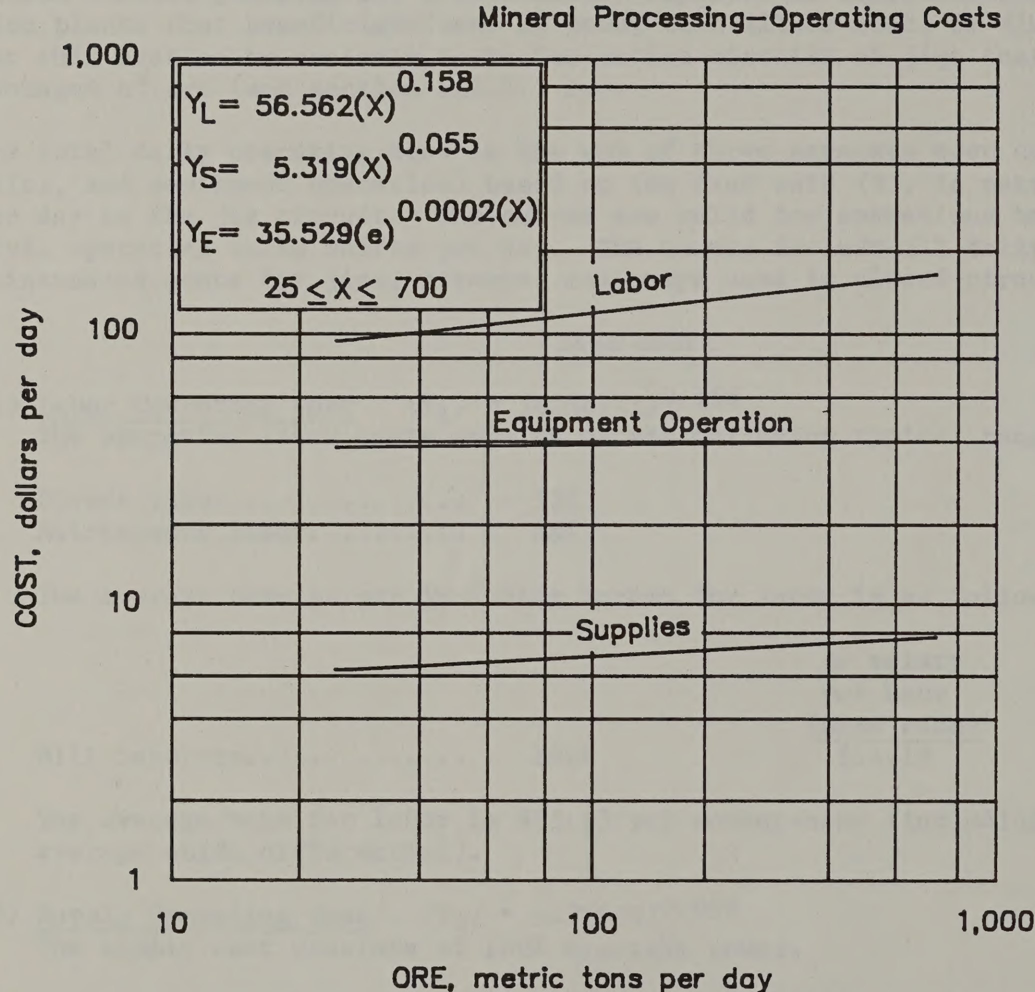
ADJUSTMENT FACTORS

<u>Screen Factors</u> The curves include costs for screens; however, in many instances screens are not employed with this type jig usage. If screens are not used, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.84$

Supply factor $(F_S) = 0.000146(X)+0.496$
where X = material to the jig circuit, in metric tons per day.

Equipment operation factor $(F_E) = 0.26$



7.1.3.2.2. Gravity separation
JIGS IN CLOSED—CIRCUIT GRINDING

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.3. BENEFICIATION

7.1.3.2.3. GRAVITY SEPARATION REICHERT CONES

The operating cost curve covers costs associated with the operation of a Reichert cone circuit to recover heavy minerals. The Reichert cone circuit includes rougher, scavenger, cleaner, and recleaner cones. The Reichert cone circuit can process ores containing 0.1% to 5.0% heavy minerals and yield a product containing a minimum of 80% heavy minerals. The feed for the Reichert circuit is assumed to be 100% minus 10 mesh at a slurry density of 60% solids by weight.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the capacity rate (X), in mt ore feed per day. The curves are valid for operations between 2,900 and 52,440 mtpd, operating one shift per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.393(X)^{0.712}$
The operating labor costs consist of the following typical range of personnel:

	Small (2,900 to 30,000 mtpd)	Large (30,000 to 52,440 mtpd)
Direct Labor...............	80%	79%
Maintenance Labor..........	20%	21%

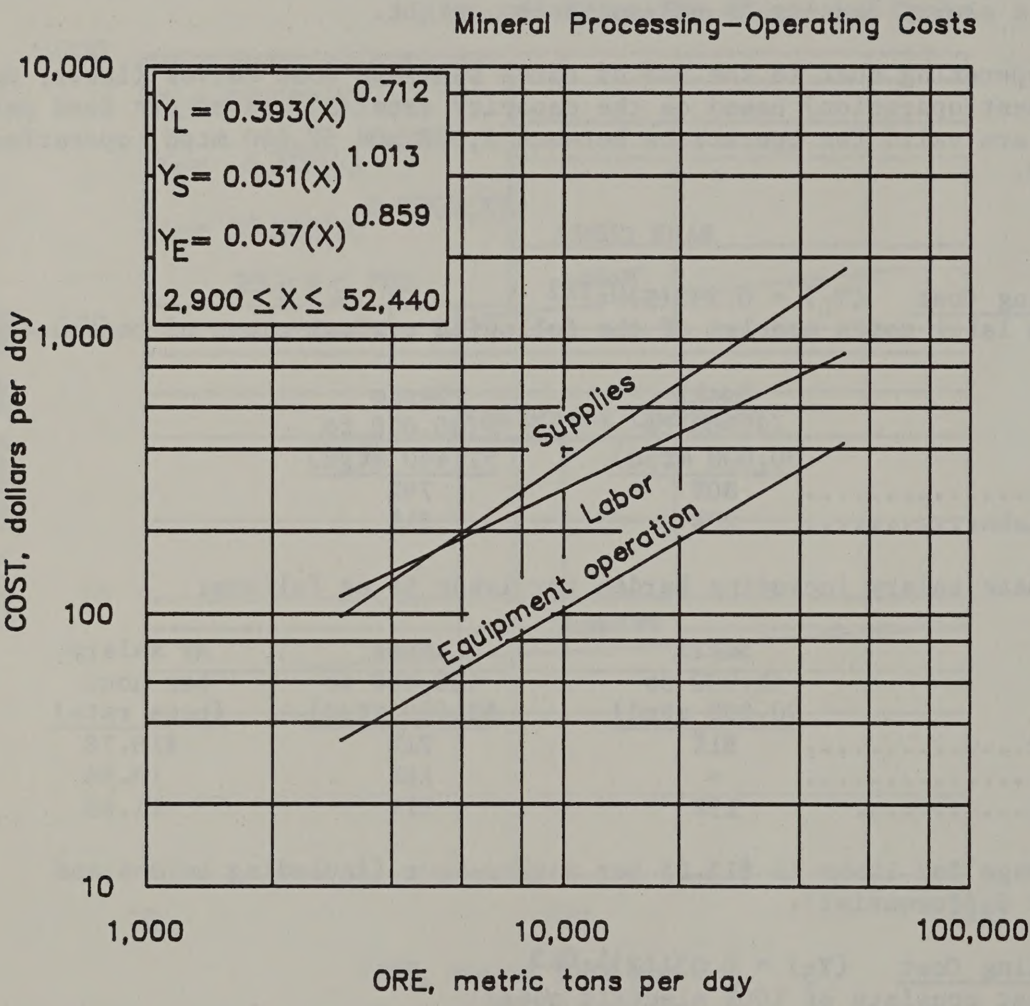
The average base salary including burden for labor is as follows:

	Small (2,900 to 30,000 mtpd)	Large (30,000 to 52,440 mtpd)	Av salary per hour (base rate)
Mill operator..............	81%	71%	$16.78
Mill helper................	-	18%	13.66
Mill laborer............	19%	11%	11.68

The average wage for labor is $15.25 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.031(X)^{1.013}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.037(X)^{0.859}$
The equipment operating curve consists of 100% for equipment and repair parts and materials. The curve includes allowance for the maintenance and repair of motors, pumps, and cones and all other pieces of equipment directly associated with the gravity separation circuit using Reichert cones.



7.1.3.2.3. Gravity separation
REICHERT CONES

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.3. BENEFICIATION

7.1.3.2.4. GRAVITY SEPARATION
SLUICING

The operating cost curve covers costs associated with the operation of a sluicing circuit to process gravels containing gold or heavy minerals. The feed for the sluicing operation is a slurry that has been prepared by screening with either a vibrating or trommel screen, or by hydraulic mining. The cost associated with washing, screening, and water distribution is not contained in the operating cost estimates for sluicing. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the capacity rate (X), in metric tons of feed material per day. The curves are valid for operations between 160 and 3,320 mtpd, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 2.165(X)^{0.490}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	83%
Maintenance labor..........	17%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Sluice operator............	100%	$17.11

The average wage for labor is $17.11 per worker-hour (including burden and average shift differential).

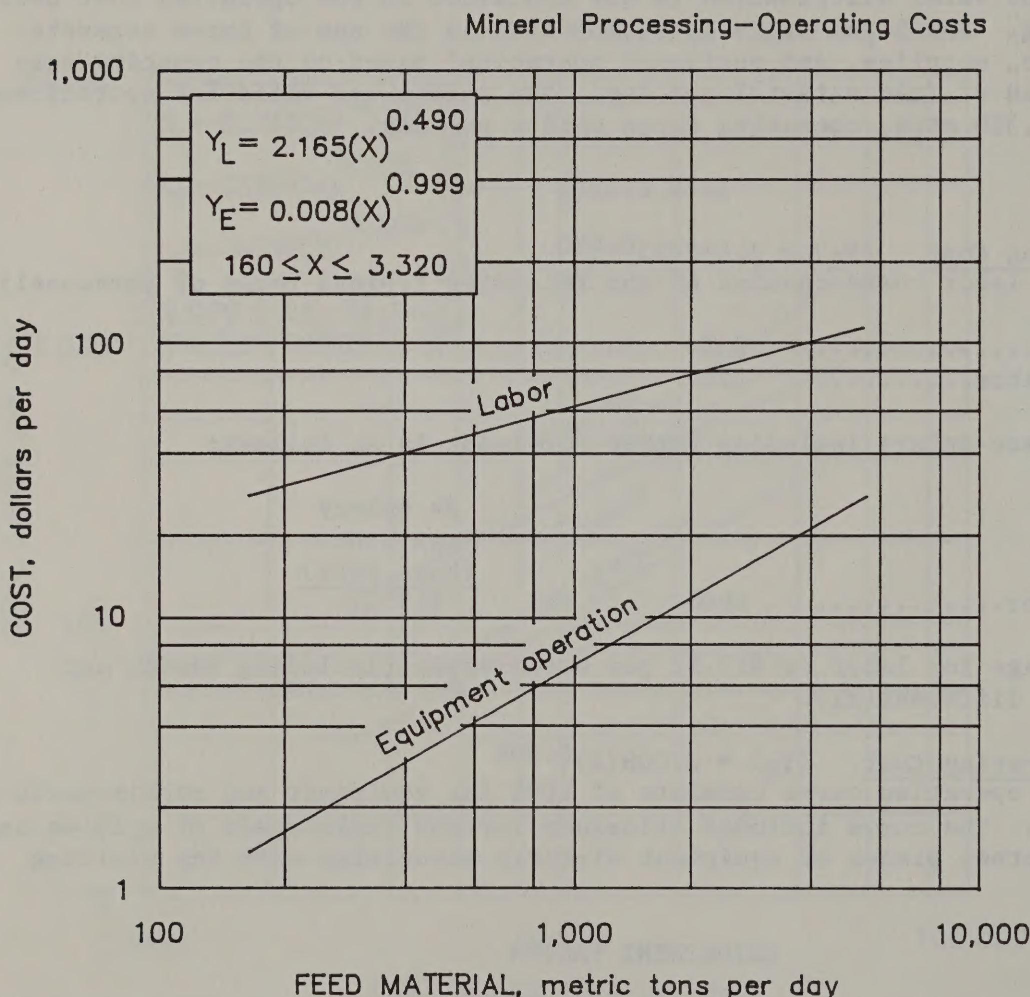
(E) Equipment Operating Cost $(Y_E) = 0.008(X)^{0.999}$
The equipment operation curve consists of 100% for equipment and repair parts and materials. The curve includes allowance for the replacement of riffles and rugs and all other pieces of equipment directly associated with the sluicing circuit.

ADJUSTMENT FACTOR

Gravel Size Factor The base curve is predicated upon processing minus 1/4-in gravel. The labor and equipment operating costs must be adjusted for differences in gravel size. Multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.796(R)^{-0.110}$

Equipment operation factor $(F_E) = 2.118(R)^{0.361}$
where R = radius of the topsize gravel, in inches.



7.1.3.2.4. Gravity separation
SLUCING

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.3. BENEFICIATION

7.1.3.2.5. GRAVITY SEPARATION SPIRALS

These curves cover the cost of separating heavy minerals from waste by the use of vertical spirals. Costs are derived for a complete system based on the input tonnage. This includes all equipment directly associated with the spiral circuits such as screens, pumps, slurry distributors, pipes, hoses, feed and discharge boxes, and the spiral units. Water usage for the curves is estimated at 0.63 m^3/mt of feed material. The equations do not cover costs for dewatering, scrubbing, drying, or for gravity separation by methods other than vertical spiraling. To account for these processes, the appropriate sections of this manual can be used.

In beach sand processing, the feed slurry is commonly dewatered prior to spiral concentrating. If this is the case, use the tailings thickening section (7.1.4.1.2.) of the manual.

This section is based on heavy mineral beach-sand operations located in the southeastern United States. Cost estimates for systems designed by other manufacturers, or used for processing other commodities, may be less accurate.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the capacity rate (X), in metric tons ore feed per day. The curves are valid for operations between 100 and 25,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated directly with spiral concentration.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 18.456(X)^{0.438}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	44%
Maintenance labor..........	56%

The average base salary including burden for labor is as follows:

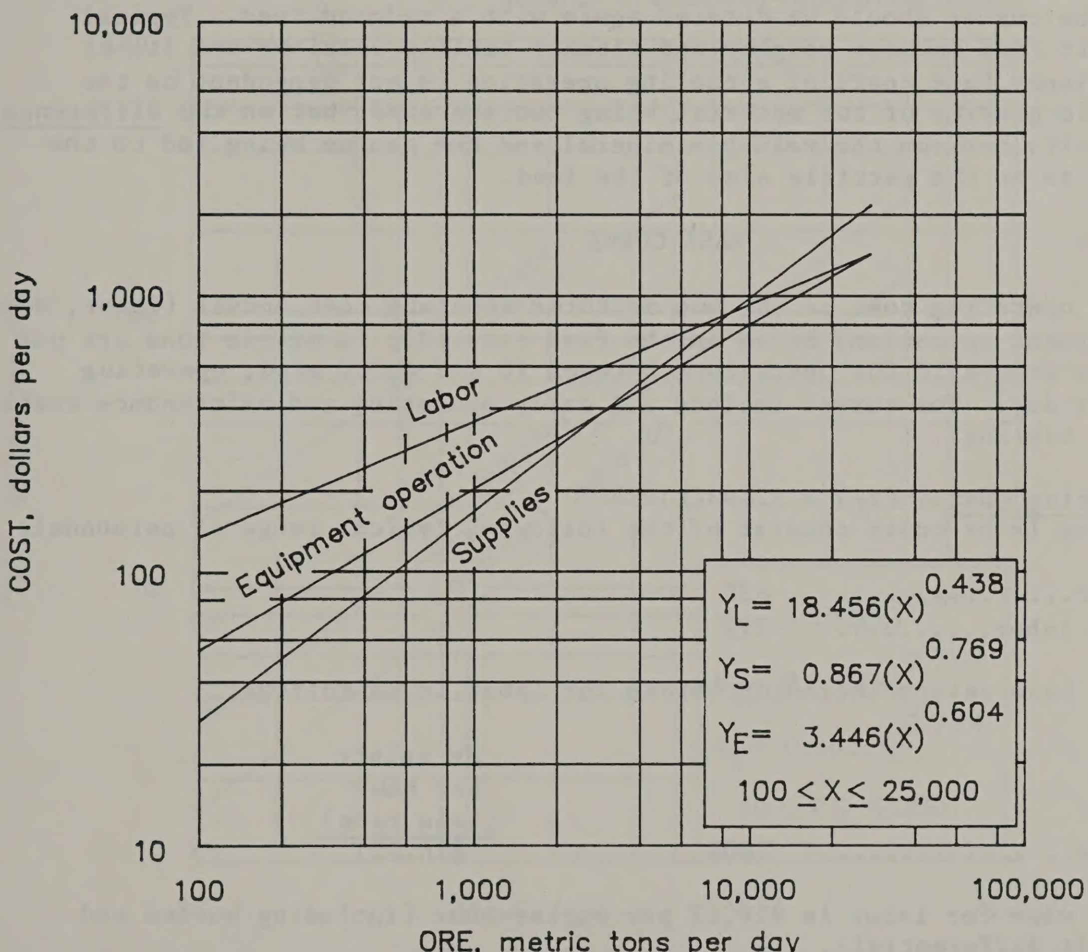
		Av salary per hour (base rate)
Plant utility person.......	100%	$14.56

The average wage for labor is $14.89 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.867(X)^{0.769}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 3.446(X)^{0.604}$
The equipment operation curve consists of 98% for repair parts and 2% for lubrication. The curve includes allowances for the replacement of motors, pump parts, screen cloths, spiral liners, hoses, and repair parts for all pieces of equipment directly associated with the spiral circuits.

Mineral Processing—Operating Costs



7.1.3.2.5. Gravity separation
SPIRALS

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.3. BENEFICIATION

7.1.3.2.6. GRAVITY SEPARATION
TABLES

These curves cover the use of shaking tables and pumps in the concentration by gravity of ground (or finely crushed) ores or concentrates of copper, gold, lead, potash, tungsten, tin, zinc, or graphite. Average washwater requirements are 2.2 m^3/mt of ore. This section covers the total daily cost of rougher tables only. If the handbook user desires to re-table or clean the product or middlings from this circuit, the curves should be entered again with a reduced feed. Typical ratios of circuit feed between rougher and cleaner tabling sections are 3:1 or 4:1. The efficiency (and cost) of a tabling operation is not dependent on the absolute specific gravity of the material being concentrated, but on the difference in specific gravity between the valuable mineral and the gangue being fed to the tables, as well as on the particle size of the feed.

BASE CURVE

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the feed rate (X), in metric tons ore per day. The curves are valid for operations between 10 and 4,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with tabling.

(L) Labor Operating Cost $(Y_L) = 3.493(X)^{0.681}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	83%
Maintenance labor..........	17%

The average base salary including burden for labor is as follows:

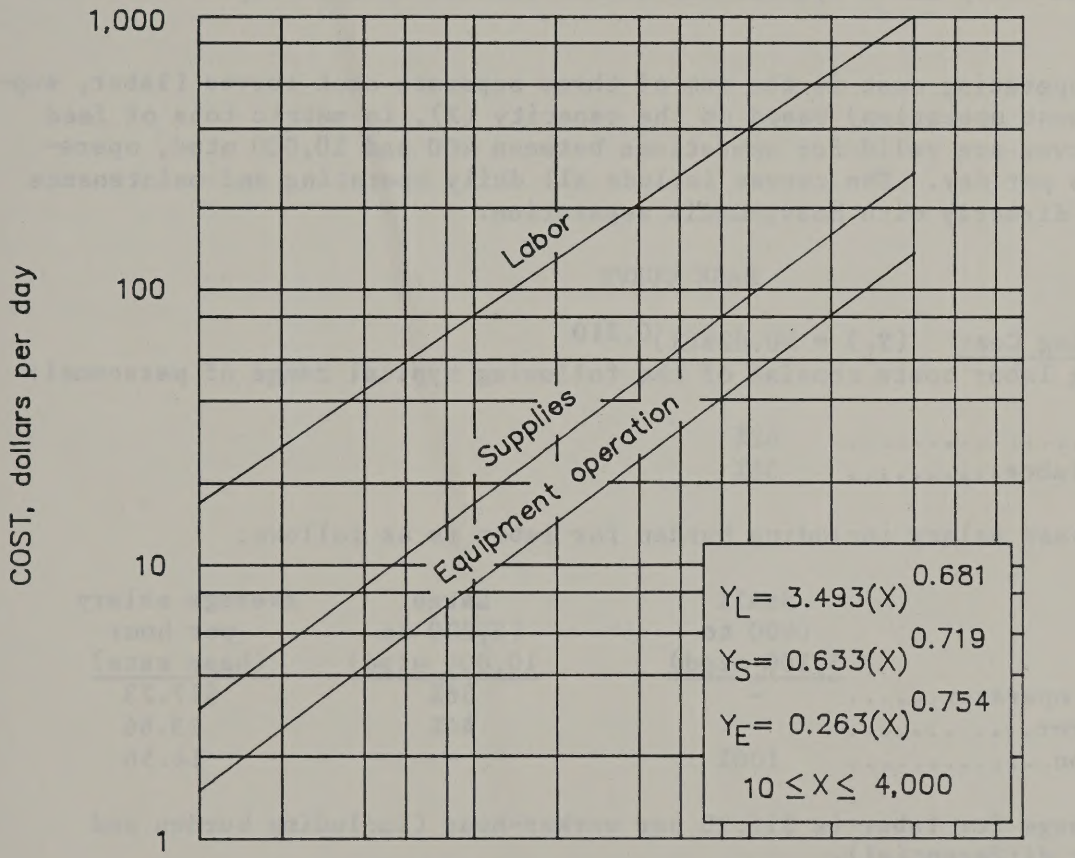
		Av salary per hour (base rate)
Floorwalkers...............	100%	$16.22

The average wage for labor is $16.22 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.633(X)^{0.719}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.263(X)^{0.754}$
The equipment operation curve covers the daily operating cost for all tables and pumps, includes allowances for parts replacemnt and maintenance, and consists of 78% for repair parts and 22% for lubrication.

Mineral Processing—Operating Costs



ORE, metric tons per day

7.1.3.2.6. Gravity separation
TABLES

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.3. BENEFICIATION

7.1.3.3. HEAVY-MEDIA SEPARATION

These curves cover the cost of separating ore minerals from waste after crushing. Each time the curve is entered, operation of a complete system is costed, including screens, demagnetizing coils, densifiers, pumps, conveyors, magnetic separators, and heavy-media equipment. The cost curves are for low-slime conditions and do not include thickeners. If thickeners are needed within the circuit, use section 7.1.4.1.1. to obtain thickening costs. The curves are representative only for dynamic cone or drum heavy-media systems and do not include Dyna Whirlpool or static systems.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the capacity (X), in metric tons of feed per day. The curves are valid for operations between 400 and 10,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated directly with heavy-media separation.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 80.029(X)^{0.310}$
The operating labor costs consist of the following typical range of personnel:

Direct labor..............	62%
Maintenance labor..........	38%

The average base salary including burden for labor is as follows:

	Small (400 to 5,200 mtpd)	Large (5,200 to 10,000 mtpd)	Average salary per hour (base rate)
Control room operator......	-	56%	$17.23
General laborer............	-	44%	13.66
Utility person.............	100%	-	14.56

The average wage for labor is $16.10 per worker-hour (including burden and average shift differential).

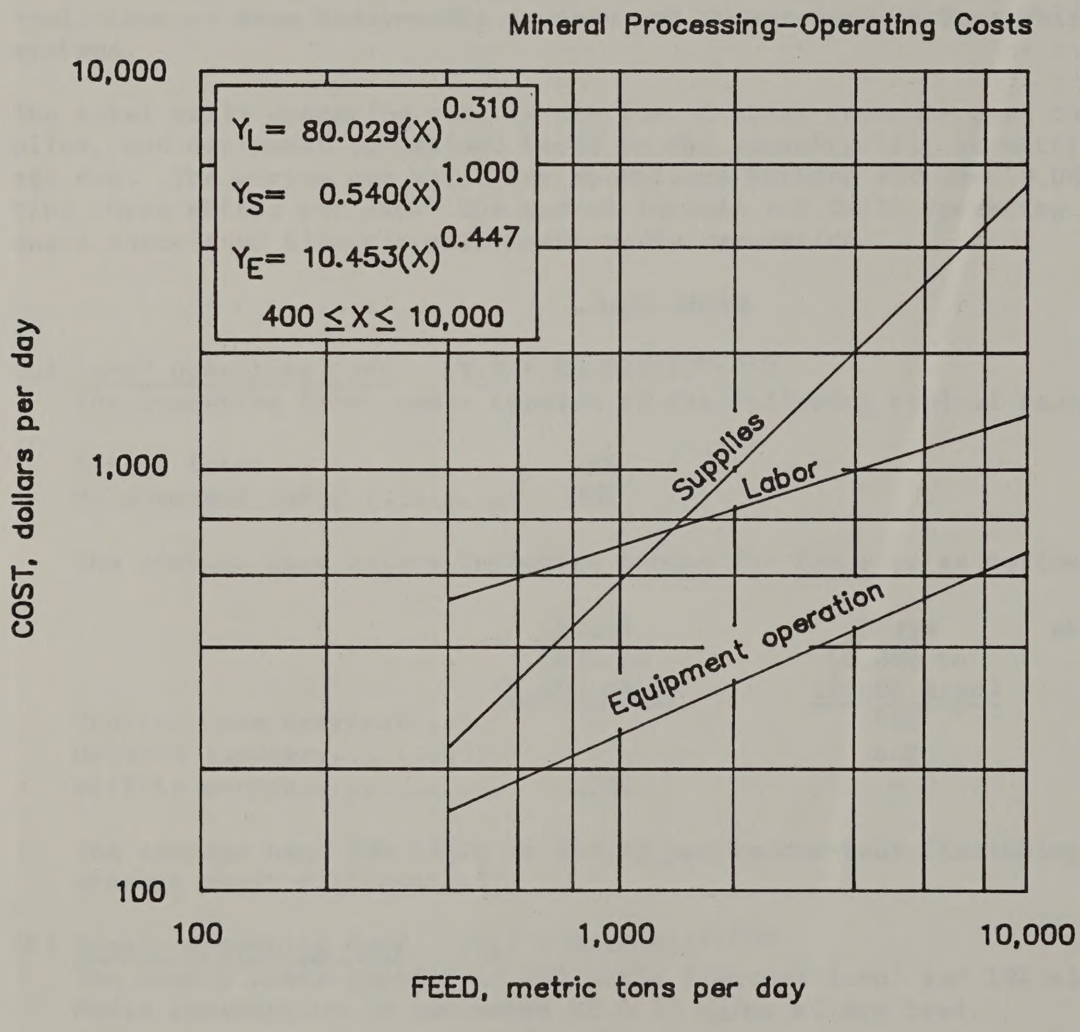
(S) Supply Operating Cost $(Y_S) = 0.540(X)^{1.000}$
The supply costs consist of 81% media (ferrosilicon) and 19% electric power. Media consumption is estimated at 0.75 kg/mt of ore feed.

(E) Equipment Operating Cost $(Y_E) = 10.453(X)^{0.447}$
The equipment operation curve consists of 99% for repair parts and 1% for lubrication. The curve includes allowances for the replacement of motors, screen cloths, conveyor belts, and repair parts for all pieces of equipment directly associated with the heavy-media circuitry.

ADJUSTMENT FACTOR

<u>Magnetite Factor</u> If magnetite is used for the media (magnetite is primarily used in coal processing) multiply the cost obtained from the curves by the following factor:

Magnetite factor $(F_M) = 0.2$



7.1.3.3. Heavy—media separation

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.3. BENEFICIATION

7.1.3.4.1. MAGNETIC SEPARATION

The curves cover the operation of magnetic separators, slurry pumps, and screens directly associated with the separating units. Each time the curve is entered, a complete magnetic separation system is costed, based on the tonnage input. This includes all equipment necessary for complete magnetic concentration of the input tonnage, but does not include costs for dewatering, desliming, or grinding and regrinding. If these processes are to be included in the circuit, the user should consult the appropriate sections of this manual. This section is based on large taconite operations that use low-intensity wet magnetic separation. For smaller operations, or operations using other types of magnetic separation, the curves will have limited accuracy.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a capacity rate (X), in metric tons of feed material per day. The curves are valid for operations between 2,000 and 100,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated directly with magnetic separation, such as screening and pumping.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 5.985(X)^{0.496}$

The operating labor costs consist of the following typical range of personnel:

	Small (2,000 to 10,000 mtpd)	Large (10,000 to 100,000 mtpd)
Direct labor...............	81%	61%
Maintenance labor..........	19%	39%

The average base salary including burden for labor is as follows:

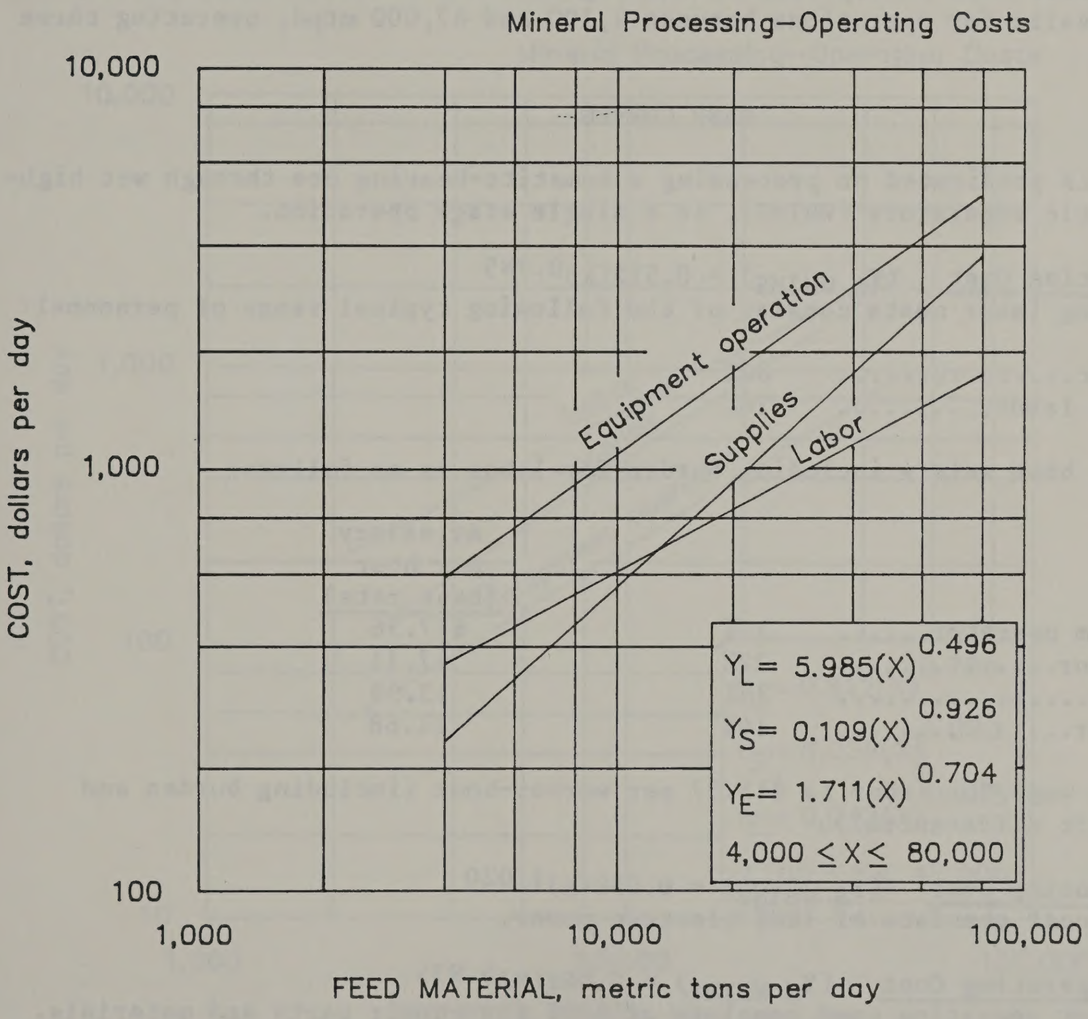
	Small (2,000 to 10,000 mtpd)	Large (10,000 to 100,000 mtpd)	Av salary per hour (base rate)
Control room operator......	-	46%	$17.56
General laborer............	100%	54%	13.99

Operating labor costs average $15.34 per worker-hour and include burden and shift differentials.

(S) Supply Operating Cost $(Y_S) = 0.109(X)^{0.926}$

The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 1.711(X)^{0.704}$
The equipment operation curve consists of 98% for repair parts and 2% for lubrication for all magnetic separation equipment. The curve includes allowances for the replacement of liners, covers, motors, pump parts, gear boxes, screens, and miscellaneous repair parts.



7.1.3.4.1. Magnetic separation

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.3. BENEFICIATION

7.1.3.4.2. HIGH INTENSITY MAGNETIC SEPARATION WET (WHIMS)

The operating costs for high-intensity magnetic separation are given on a metric ton per day of feed basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the capacity rate (X), in metric tons of dry feed to the magnetic separation circuit per day. The curves are valid for operations between 2,100 and 47,000 mtpd, operating three shifts per day.

BASE CURVES

The base curve is predicated on processing a hematite-bearing ore through wet high-intensity magnetic separators (WHIMS), in a single stage operation.

(L) Labor Operating Cost $(Y_{L\ WHIMS}) = 0.512(X)^{0.785}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	86%
Maintenance labor..........	14%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator......	30%	$17.56
Mill operator..............	22%	17.11
Mill helper................	34%	13.99
Mill laborer...............	14%	11.68

The average wage for labor is $15.37 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_{S\ WHIMS}) = 0.038(X)^{1.020}$
The supply cost consists of 100% electric power.

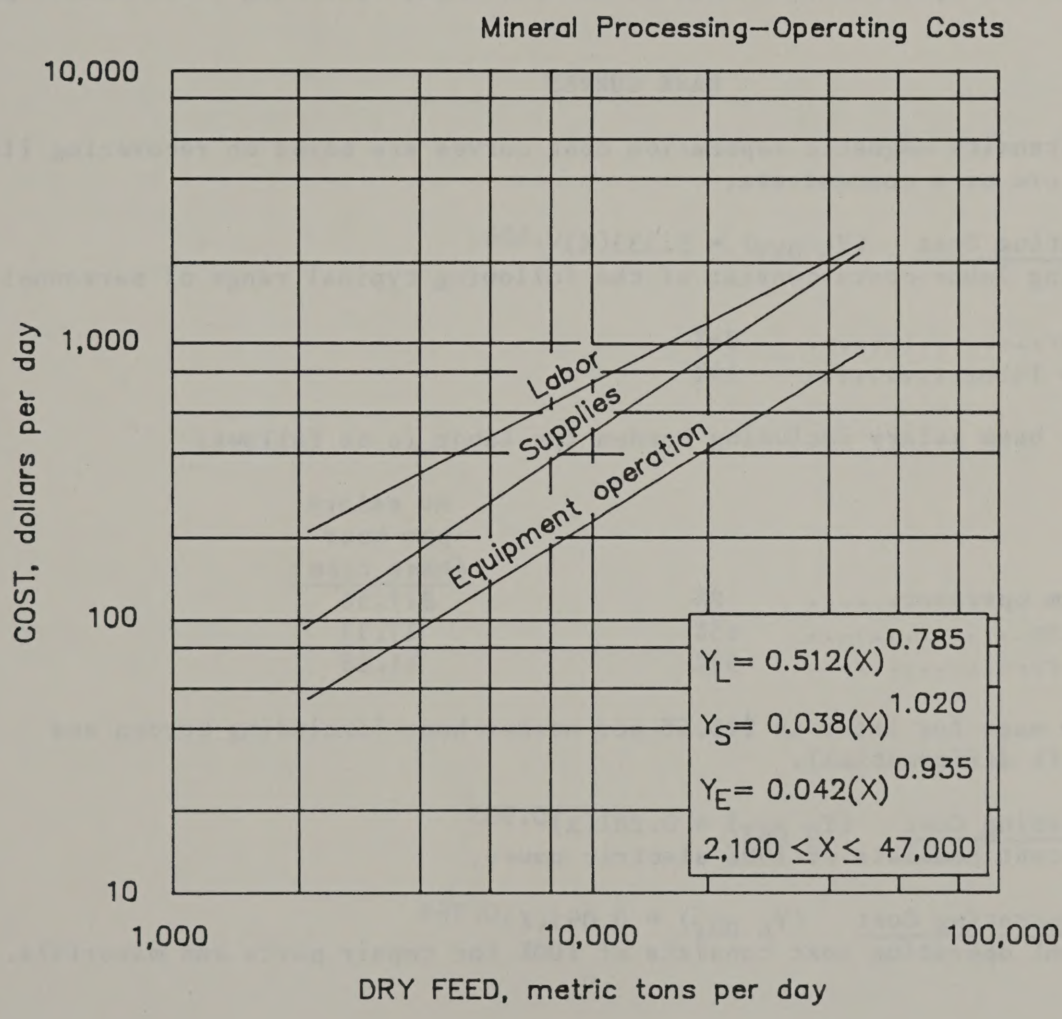
(E) Equipment Operating Cost $(Y_{E\ WHIMS}) = 0.042(X)^{0.935}$
The equipment operating cost consists of 100% for repair parts and materials.

ADJUSTMENT FACTOR

Addition of a Cleaner Stage To produce a higher quality product, a cleaner stage may be added. To adjust for a cleaner stage, multiply the supply and equipment costs obtained from the curves by the following factors:

Supply factor $(F_{S\ WHIMS}) = 1.22$

Equipment operation factor $(F_{E\ WHIMS}) = 1.14$



7.1.3.4.2. High intensity magnetic separation—wet (WHIMS)

7.1. MINERAL PROCESSING - OPERATING COSTS

7.1.3. BENEFICIATION

7.1.3.4.3. HIGH-INTENSITY MAGNETIC SEPARATION DRY

The operating costs for high-intensity magnetic separation are given on a metric ton per day of feed basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the capacity rate (X), in metric tons of ore to the magnetic separation circuit per day. The curves are valid for operations between 80 and 900 mtpd, operating three shifts per day.

BASE CURVES

The dry high-intensity magnetic separation cost curves are based on recovering ilmenite from an ore or a concentrate.

(L) Labor Operating Cost $(Y_{L\ DRY}) = 5.333(X)^{0.654}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	86%
Maintenance labor..........	14%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator......	2%	$17.56
Mill operator..............	65%	17.11
Mill laborer...............	32%	11.68

The average wage for labor is $15.68 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_{S\ DRY}) = 0.281(X)^{0.935}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_{E\ DRY}) = 0.095(X)^{0.969}$
The equipment operating cost consists of 100% for repair parts and materials.

ADJUSTMENT FACTOR

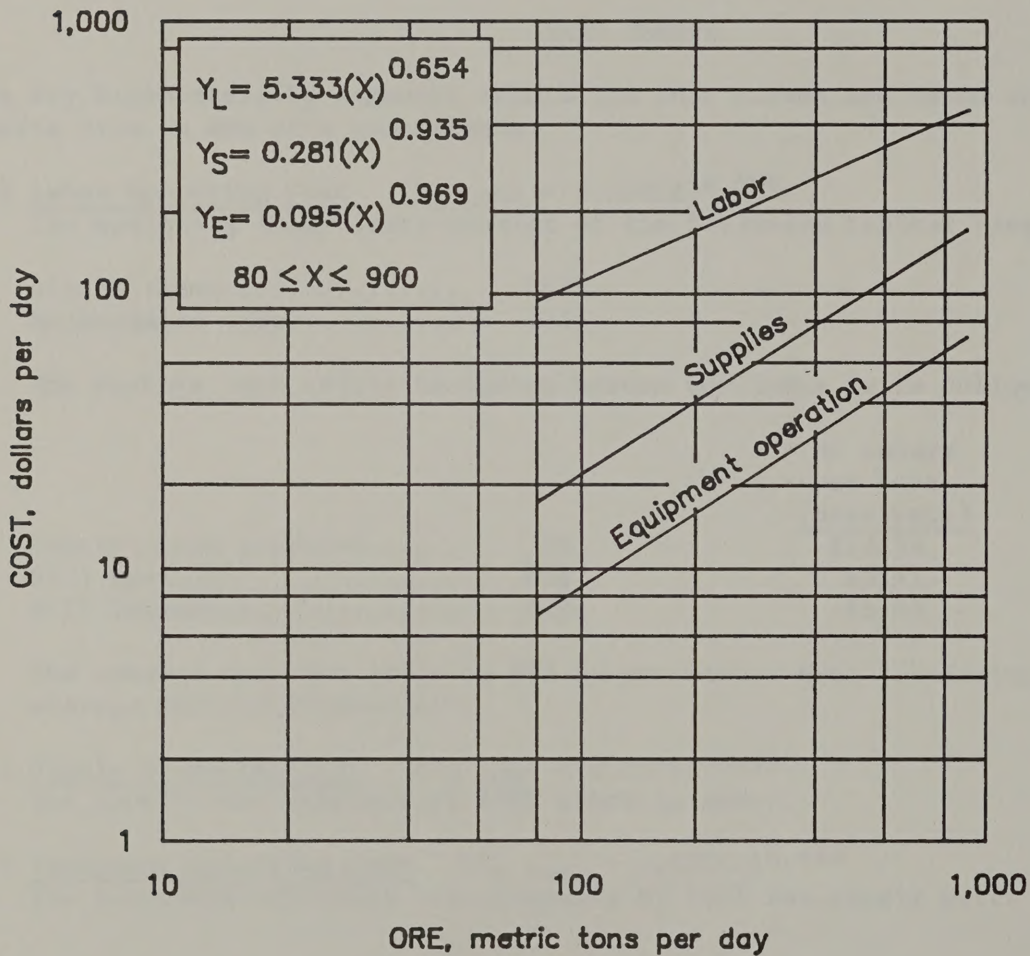
Feed Rate The base curves are based on feeding a high-intensity induced roll separator at a dry feed rate of 25.8 (kg/h)/cm of roll length. The feed rate can vary from 9 to 179 (kg/h)/cm depending on the application. For strategic commodities, this range is 18 to 55 (kg/h)/cm. To adjust for different hourly feed rates, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.001(25.8/F)^{0.653}$

Supply factor $(F_S) = 1.001(25.8/F)^{0.932}$

Equipment operation factor $(F_E) = 1.001(25.8/F)^{0.967}$
where F = new hourly feed rate, in kilograms per hour per centimeter of roll length.

Mineral Processing—Operating Costs



7.1.3.4.3. High intensity magnetic separation—dry

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.3. BENEFICIATION

7.1.3.5. PHOTOMETRIC SEPARATION

The operating cost curves for photometric separation are given on a metric ton per day basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the capacity rate (X), in metric tons of feed material to the sorter plant per day. The curves are valid for operations between 925 and 7,280 mtpd, operating on a continuous basis.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 1.285(X)^{0.728}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	96%
Maintenance labor..........	4%

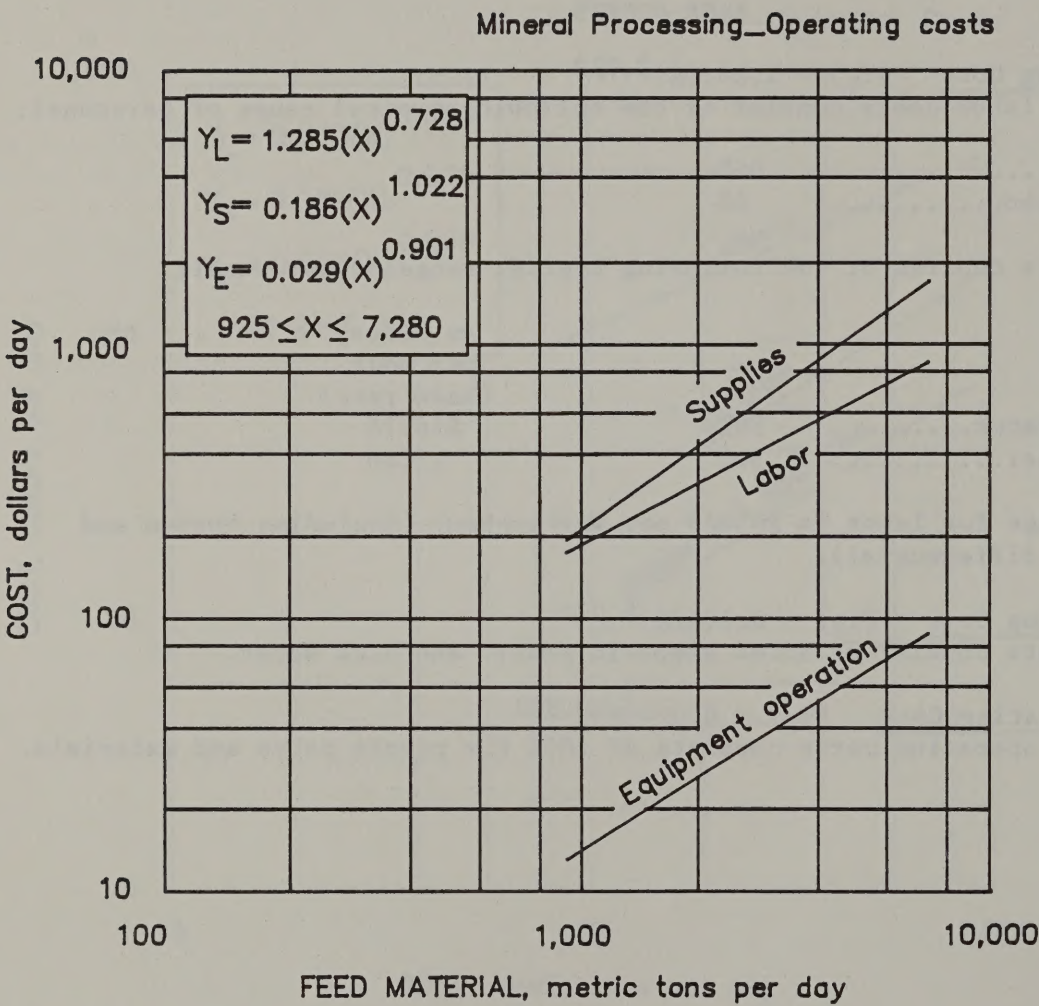
The labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Mill operator.........	50%	$16.78
Mill helper...........	50%	13.66

The average wage for labor is $15.28 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.186(X)^{1.022}$
The supply costs consist of 93.8% electric power. and 6.2% water.

(E) Equipment Operating Cost $(Y_E) = 0.029(X)^{0.901}$
The equipment operation curve consists of 100% for repair parts and materials.



7.1.3.5. Photometric separation

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.4. SOLID-LIQUID SEPARATION

7.1.4.1.1. SEDIMENTATION
CONCENTRATE THICKENING

Concentrate thickening is the partial dewatering of the concentrate pulp in preparation for effective filtration and, in some cases, drying.

The curves include all daily operating and maintenance costs associated with continuous concentrate thickening, but apply only to the operation of conventional concentrate thickeners and do not make allowances for the use of high-capacity, tray, deep-cone, or middling thickeners. In addition, the curves do not apply to the operation of clarifiers or countercurrent decantation arrangements.

1. Costs are based on current industry preference for installation of a single large thickener, rather than several smaller thickeners of the same or different sizes, whenever possible. Large-capacity operations may use several thickeners because of maximum design-size limitations.

2. The curves cannot be directly applied to thickeners processing light (river or lake water clarification, metallic oxides, and brine clarification), some standard (magnesium oxide and lime or brine softening), or extra-heavy (uranium countercurrent decantation, iron ore concentrate, iron pellet feed, and titanium ilmenite) pulps. Size of solids is approximately 68% smaller than 200 mesh and 10% larger than 65 mesh.

3. Cost are applicable to the following thickener operating parameters:

Solids loading........................	$0.77\ m^2/mtpd$[1]
Specific gravity of solution...........	1.00
Specific gravity of underflow slurry...	1.46
Inflow slurry solid percent...........	25% by weight
Underflow slurry solid percent.........	50% by weight

[1]The cost curves are actually based on $0.93m^2/mtpd$, an increase of approximately 25% for safety and temporary storage. See table A-1 for unit areas.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the production rate (X), in metric tons of concentrate per day, on a dry basis. The curves are valid for operations between 5 and 100,000 mtpd, operating three shifts per day. If more than one concentrate is being produced and thickened, the curves should be entered as often as necessary using the appropriate daily tonnage rates and unit area settling rates.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.005(X)+33.289$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	19%
Maintenance labor..........	81%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Utility person.............	100%	$14.89

The average wage for labor is $14.89 per worker-hour (including burden and average shift differential).

No operating personnel are specifically assigned full time for thickener operation. Annual maintenance labor, prorated to a daily basis for this curve, is required for overhaul and/or lubrication.

(S) Supply Operating Cost $(Y_S) = 1.614(X)^{0.547}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.991(X)^{0.496}$
The equipment operation cost generally consists of only annual maintenance, which includes 92% for overhaul and repair parts and 8 % for lubrication.

ADJUSTMENT FACTORS

Amorphous or Colloidal Tailings The thickener area should be approximately doubled for amorphous or colloidal tailings. Costs should be increased accordingly.

Flocculation Factor Flocculants are high-molecular weight polyelectrolytes of chemically modified natural organic materials used to promote settling. A wide range of unit area reductions is possible in designing a thickener, depending upon which flocculant is added to the feed. In an existing thickener, throughputs can be markedly increased, sometimes by a factor of 10 or more. For the basis of this section, the following costs should be added to the operating curves given above if flocculants are added:

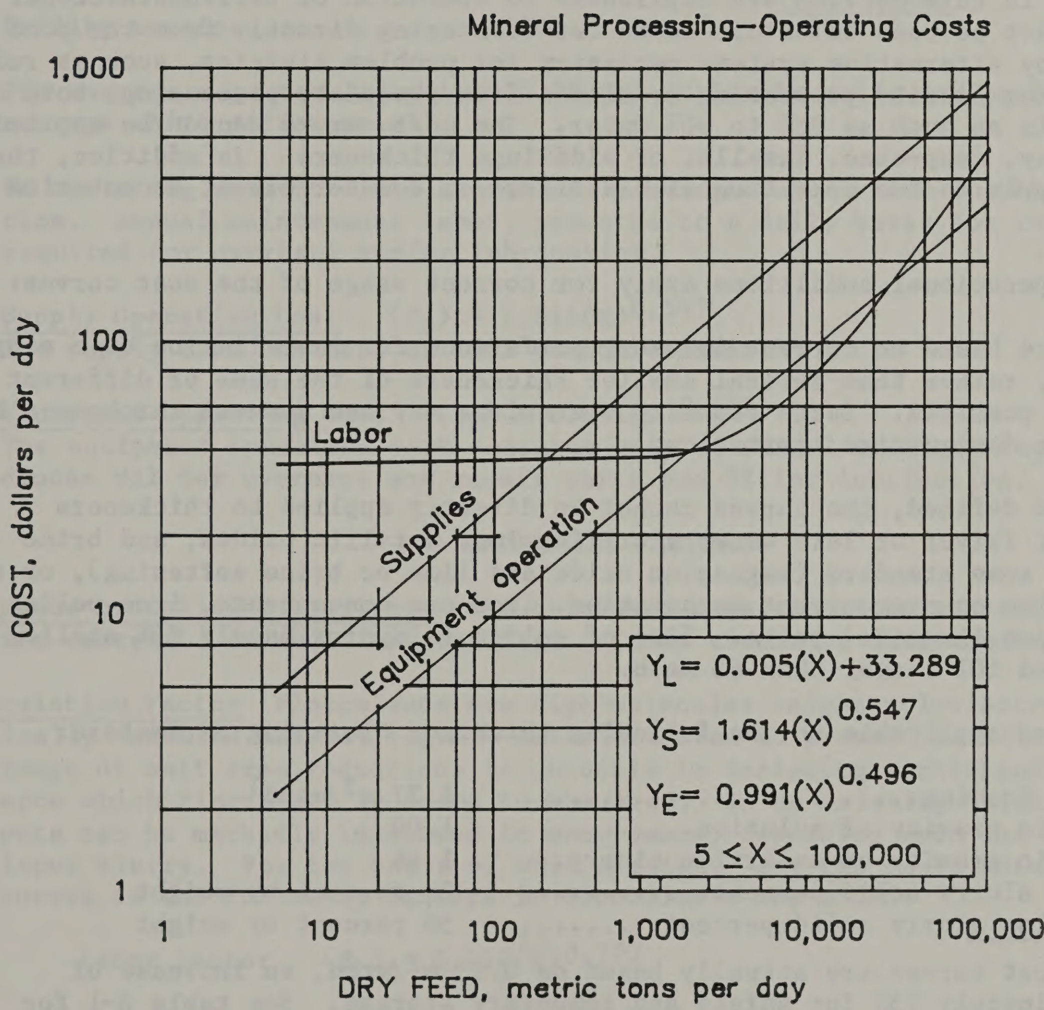
Labor factor $(F_L) = 0.110(X)^{0.722}$

Flocculation polymer cost
Supply factor $(F_{S\ POLYMER}) = 0.028(X)^{1.000}$

Flocculation power cost
Supply factor $(F_{S\ POWER}) = 0.011(X)^{0.745}$

where X = dry concentrate, in metric tons per day.

These curves are based on a polymer costing $2.76 per kilogram in emulsion form being added at the rate of 3 mg/L of thickener slurry feed and on a slurry volume of 3,392 L of slurry per metric ton of dry solids.



7.1.4.1.1. Sedimentation
CONCENTRATE THICKENING

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.4. SOLID-LIQUID SEPARATION

7.1.4.1.2. SEDIMENTATION
TAILINGS THICKENING

Dewatering of tailings slurries through sedimentation and decantation in ponds and basins is usually preceded by preliminary dewatering with thickeners to reduce the slurry volume prior to transportation to the pond and to facilitate water reuse.

The cost curves in this section are applicable to operation of tailingsthickener systems but cannot be used to obtain costs for dewatering directly from the pond or for dewatering by alternative systems necessary for problem slurries, such as red mud resulting from bauxite processing or slimes from phosphate processing, both of which may contain as much as 85% to 90% water. The cost curves cannot be applied to high-rate tray, deep-cone, lamella, or middlings thickeners. In addition, the curves do not apply to the operation of clarifiers or countercurrent decantation arrangements.

The following operational conditions apply for correct usage of the cost curves:

1. Costs are based on current industry preference for installation of a single large thickener, rather than several smaller thickeners of the same or different sizes, whenever possible. Large capacity operations may use several thickeners because of maximum design-size limitations.

2. Thus, as defined, the curves cannot be directly applied to thickeners processing light (river or lake water clarification, metallic oxides, and brine clarification), some standard (magnesium oxide and lime or brine softening), or extra-heavy (uranium countercurrent decantation, iron ore concentrate, iron pellet feed, and titanium ilmenite) pulps. Size of solids is approximately 68% smaller than 200 mesh and 10% larger than 65 mesh.

3. Costs are applicable to the following thickener operating parameters:

Solids loading.........................	0.77 m^2/mtpd[1]
Specific gravity of solution...........	1.00
Specific gravity of underflow slurry...	1.46
Inflow slurry solid percent............	25 percent by weight
Underflow slurry solid percent.........	50 percent by weight

[1]The cost curves are actually based on 0.93 m^2/mtpd, an increase of approximately 25% for safety and temporary storage. See table A-1 for unit areas.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the feed rate (X), in metric tons of tailings per day determined on a dry basis. The curves are valid for operations between 5 and 100,000 mtpd, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.005(X)+33.289$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	19%
Maintenance labor..........	81%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Utility person.............	100%	$14.56

The average wage for labor is $14.89 per worker-hour (including burden and average shift differential).

No operating personnel are specifically assigned full time for thickener operation. Annual maintenance labor, prorated to a daily basis for this curve, is required for overhaul and/or lubrication.

(S) Supply Operating Cost $(Y_S) = 1.614(X)^{0.547}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.991(X)^{0.496}$
The equipment operation cost consists only of annual maintenance, which includes 92% for overhaul and repair parts and 8% for lubrication.

ADJUSTMENT FACTORS

Amorphous or Colloidal Tailings The thickener area should be approximately doubled for amorphous or colloidal tailings. Costs should be increased accordingly.

Flocculation Factor Flocculants are high-molecular weight polyelectrolytes of chemically modified natural organic materials used to promote settling. A wide range of unit area reductions is possible in designing a thickener, depending upon which flocculant is added to the feed. In an existing thickener, throughputs can be markedly increased in many cases, depending upon the nature of the input slurry. For the basis of this section, add the costs obtained from the curves to the following factors if flocculants are added:

Labor factor $(F_L) = 0.110(X)^{0.722}$

Flocculation polymer cost

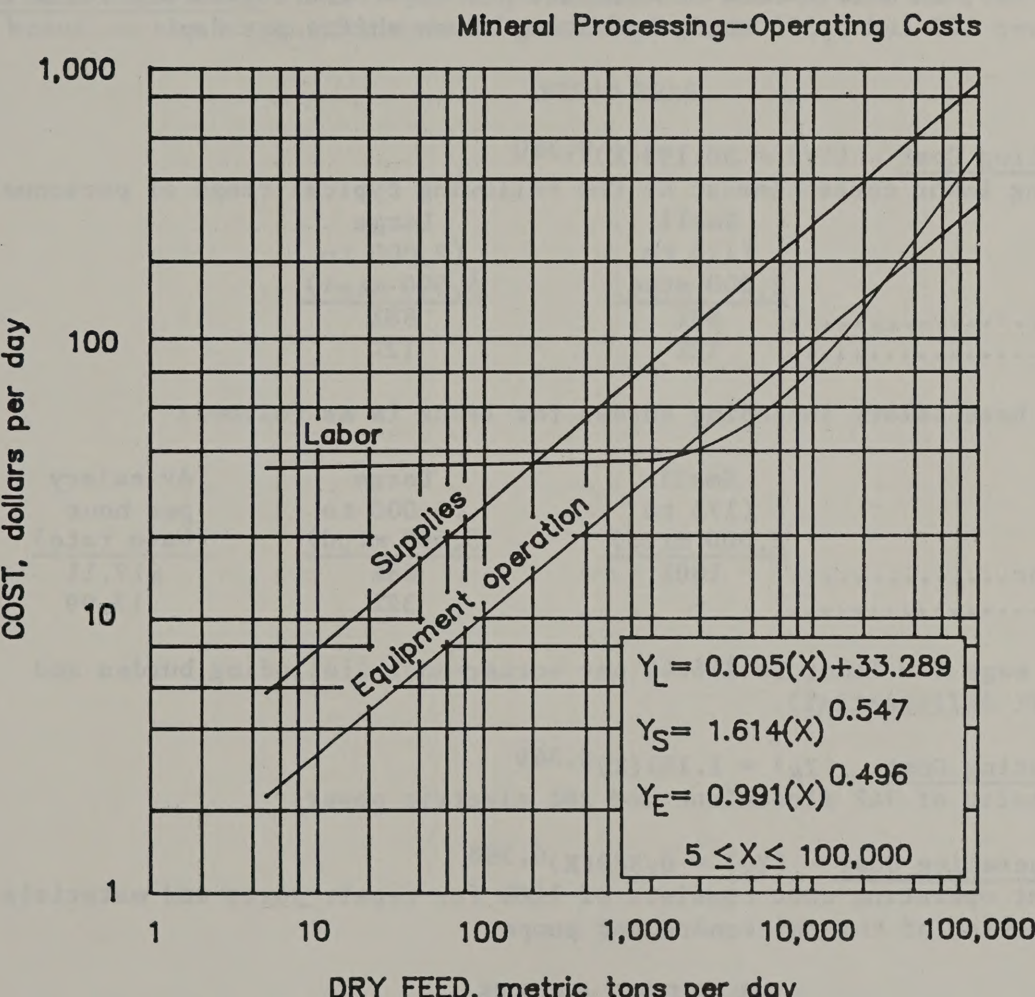
Supply factor $(F_{S\ POLYMER}) = 0.028(X)^{1.000}$

Flocculation power cost

Supply factor $(F_{S\ POWER}) = 0.011(X)^{0.745}$

where X = dry tailings, in metric tons per day.

These curves are based on a polymer costing $2.76 per kilogram in emulsion form being added at the rate of 3 mg/L of thickener slurry feed and on a slurry volume of 3,392 L of slurry per metric ton of dry solids.



7.1.4.1.2. Sedimentation
TAILINGS THICKENING

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.4. SOLID-LIQUID SEPARATION

7.1.4.1.3. SEDIMENTATION COUNTERCURRENT DECANTATION

The operating cost curves for countercurrent decantation cover the operation of a 4-stage circuit at a settling area of 0.06 m^2/mtpd. The circuit includes the operation of thickeners and pumps. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the production rate (X), in metric tons concentrate per day. The curves are valid for operations between 175 and 5,500 mtpd, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 30.193(X)^{0.380}$

The operating labor costs consist of the following typical range of personnel:

	Small (175 to 2,000 mtpd)	Large (2,000 to 5,500 mtpd)
Operations.................	88%	88%
Maintenance................	12%	12%

The average base salary including burden for labor is as follows:

	Small (175 to 2,000 mtpd)	Large (2,000 to 5,500 mtpd)	Av salary per hour (base rate)
Mill operator..............	100%	68%	$17.11
Mill helper................	-	32%	13.99

The average wage for labor is $16.42 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.181(X)^{0.849}$

Supplies consist of 74% flocculant and 26% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.989(X)^{0.388}$

The equipment operating cost consists of 100% for repair parts and materials for the operation of the thickeners and pumps.

ADJUSTMENT FACTORS

Number of Thickener Units The cost curves are based on the operation of a four-stage circuit. To adjust for each additional thickener unit, multiply the costs obtained from the curves by the following factors:

Supply factor $(F_{S\ EXTRA}) = 1.06$

Equipment operation factor $(F_{E\ EXTRA}) = 1.19$

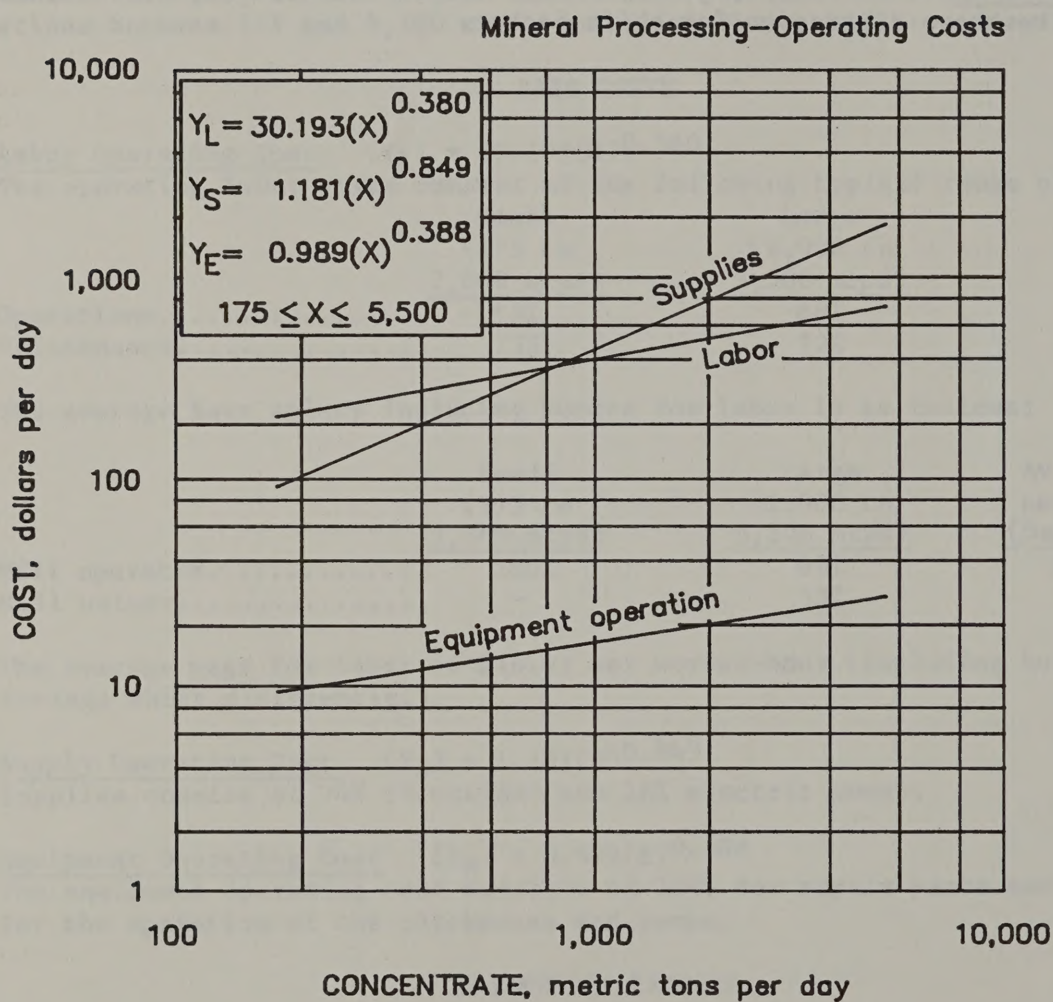
Conversely, to adjust for less than four thickener units, multiply the costs obtained from the curves by the following factors for each unit:

Supply factor $(F_{S\ FEWER}) = 0.94$

Equipment operation factor $(F_{E\ FEWER}) = 0.81$

Shift Factor The curve is based on a three-shift-per-day operation. Typically, counter-current decantation circuits are operated on a continuous basis to maintain steady flow rates between the individual thickener units. No adjustment factor for a oneor two-shift operation is recommended for this unit process.

Feed Rate Adjustment Accordingly, no adjustment factor for feed rate is recommended based on the above discussion for shift factor.



7.1.4.1.3. Sedimantation
COUNTER CURRENT DECANTATION

7.1. MINERAL PROCESSING--OPERATING COST

7.1.4. SOLID-LIQUID SEPARATION

7.1.4.2.1. CONCENTRATE FILTRATION
VACUUM, DISK, AND DRUM FILTRATION

During filtration, the water content of the thickened concentrate pulp is reduced from approximately 50% to 12%. Unless subsequent drying is required, the filtration process is the final step used in producing a concentrate product.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the output rate (X), in metric tons dry concentrate per day. The curves are valid for operations between 5 and 60,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with continuous-vacuum filtration, but do not include costs related to the auxiliary use of steam hoods or dewatering reagents. In particular, the curves apply to the operation of rotary-disc filter equipment; however, for the operation of drum-type or horizontal filter equipment, the curves still provide approximations of costs.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 18.964(X)^{0.470}$
The labor costs consist of the following typical range of personnel:

Direct labor...............	62%
Maintenance labor..........	38%

The average base salary including burden for labor is as follows:

		Av Salary per hour (base rate)
Filter-dryer operators.....	100%	$16.22

The average wage for labor is $16.22 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.792(X)^{0.843}$
The supply costs consist of 91% electric power and 9% filter media (the filter medium is polyethylene cloth). If flocculants, filter aids, or other reagents (for improving dewatering performance) are used in the filtration process, their cost(s) should be added to the base supplies cost.

(E) Equipment Operating Cost $(Y_E) = 4.642(X)^{0.528}$
The equipment operating cost consists of 93% for overhaul and repair parts and 7% for lubrication.

ADJUSTMENT FACTORS

Filtration Rate Factor The operating cost curves are predicated on a filtration rate of 490 (kg/m^2)/hr (approximately 100 (lb/ft^2)/hr). To allow for different filtration rates, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = (F/490)^{0.470}$

Supply factor $(F_S) = (F/490)^{0.843}$

Equipment operation factor $(F_E) = (F/490)^{0.528}$
where F = actual filtration rate, in kilograms per square meter per hour.

Pressure Filter Factor To account for the use of automatic pressure filters (e.g., Larox or Lasta-type filter presses) in place of the rotary-disk filters, multiply the costs obtained from the curves by the following factors:

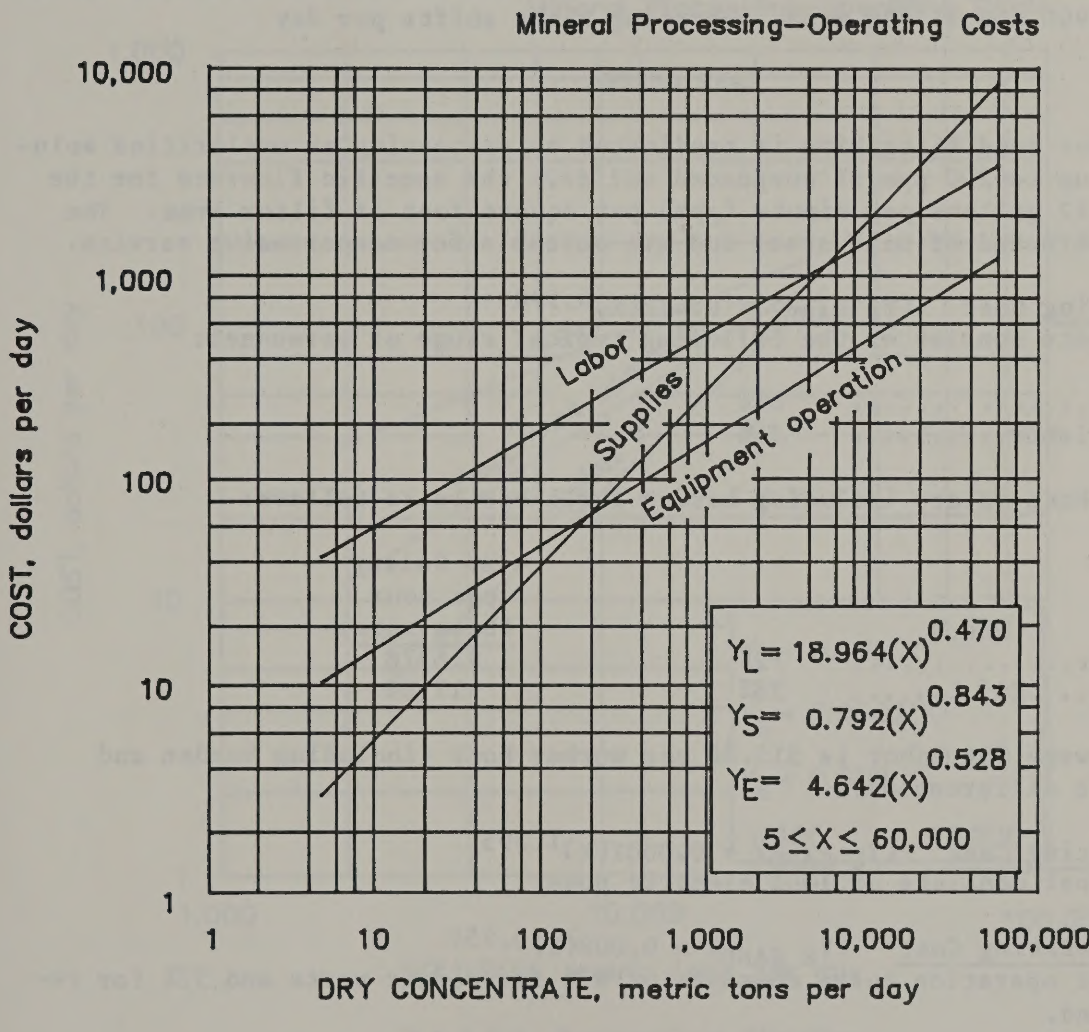
Supply factor $(F_S) = 0.56$

Equipment operation factor $(F_E) = 4.5$

The water content of the pressure-filtered concentrate will also be less than that obtained from rotary-disc filtration (approximately 8% instead of 12%).

Filter Medium Factor If the filter medium is not polyethylene cloth, the filter media cost should also be adjusted to reflect the material being used.

Steam Drying Factor If the filtration machines use auxiliary steam drying, the extra operating costs (labor, electric power, overhaul and repair parts, and lubrication) should be added to the applicable base curve costs.



7.1.4.2.1. Concentrate filtration
VACUUM, DISK, AND DRUM FILTRATION

7.1. MINERAL PROCESSING--OPERATING COST

7.1.4. SOLID-LIQUID SEPARATION

7.1.4.2.2. CONCENTRATE FILTRATION PRESSURE FILTRATION--SAND

The operating costs for pressure filtration are given on a metric ton per day of clarified solution basis. The costs include the operation of the feed pumps, filters, and ancillary equipment. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having an adjusted feed rate (X), in metric tons of solution per day. The curves are valid for operations between 1,900 and 31,900 mtpd, operating three shifts per day.

BASE CURVE

The base curve for sand filtration is predicated on processing an unclarified solution containing up to 200 ppm of suspended solids. the specific flowrate for the sand filters is 12 gallons per minute (gpm) per square foot of filter area. The filters are constructed of mild steel and are suitable for noncorrosive service.

(L) Labor Operating Cost $(Y_{L\ SAND}) = 0.422(X)^{0.590}$
The labor costs consist of the following typical range of personnel:

Direct labor...............	65%
Maintenance labor..........	35%

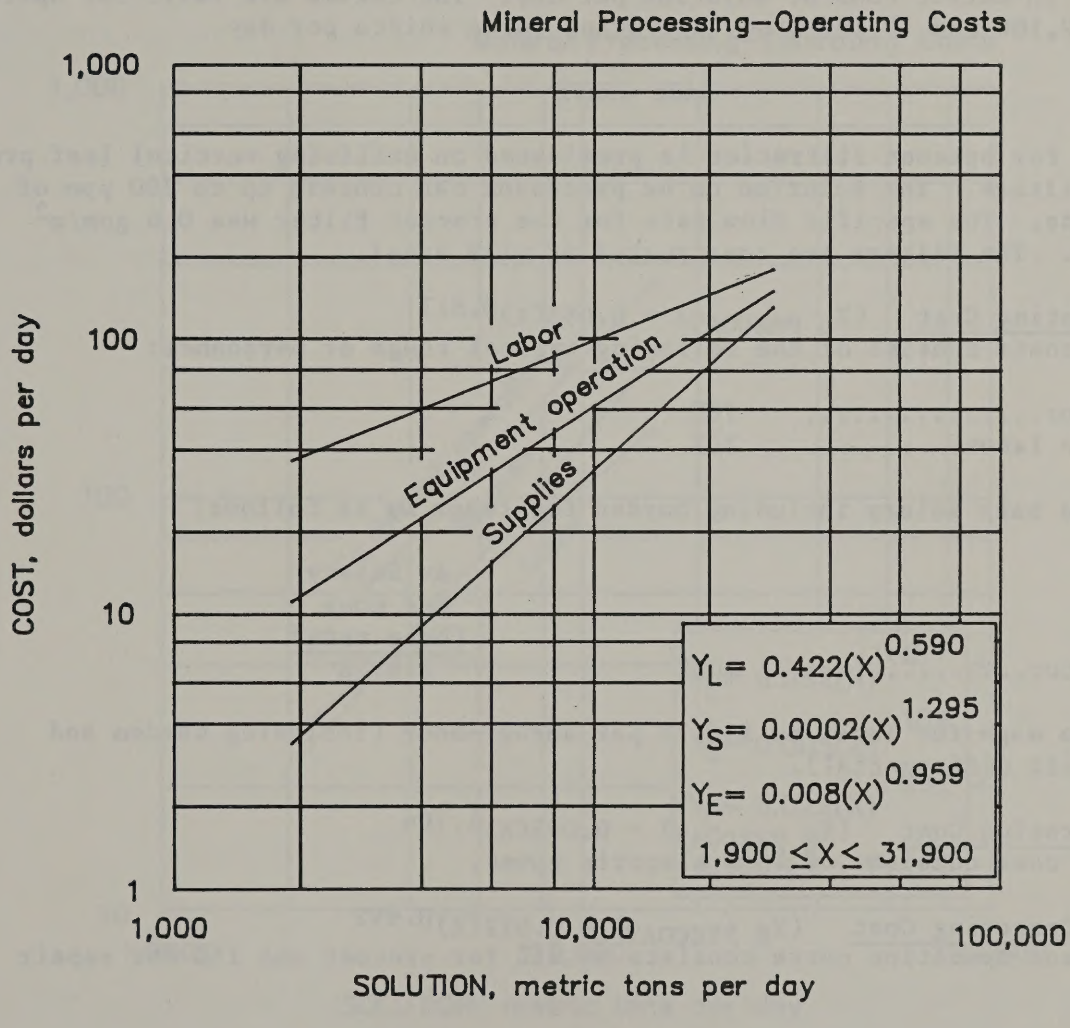
The average base salary including burden for labor is as follows:

		Av Salary per hour (base rate)
Mill operator..............	72%	$16.78
Mill laborer...............	28%	11.68

The average wage for labor is $15.86 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_{S\ SAND}) = 0.0002(X)^{1.295}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_{E\ SAND}) = 0.008(X)^{0.959}$
The equipment operation curve consists of 47% for repair parts and 53% for replacement sand.



7.1.4.2.2. Concentrate filtration
PRESSURE FILTRATION—SAND

7.1. MINERAL PROCESSING--OPERATING COST

7.1.4. SOLID-LIQUID SEPARATION

7.1.4.2.3. CONCENTRATE FILTRATION
PRESSURE FILTRATION - PRECOAT

The operating costs for pressure filtration are given on a metric ton per day of clarified solution basis. The costs include the operation of the feed pumps, filters, and ancillary equipment. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having an adjusted feed rate (X), in metric tons of solution per day. The curves are valid for operations between 2,100 and 16,100 mtpd, operating three shifts per day.

BASE CURVE

The base curve for precoat filtration is predicated on utilizing vertical leaf pressure precoat filters. The solution to be processed can contain up to 200 ppm of suspended solids. The specific flow rate for the precoat filter was 0.6 gpm/m^2 of filter area. The filters are constructed of mild steel.

(L) Labor Operating Cost $(Y_{L\ PRECOAT}) = 0.052(X)^{0.817}$
The labor costs consist of the following typical range of personnel:

Direct labor...............	70%
Maintenance labor..........	30%

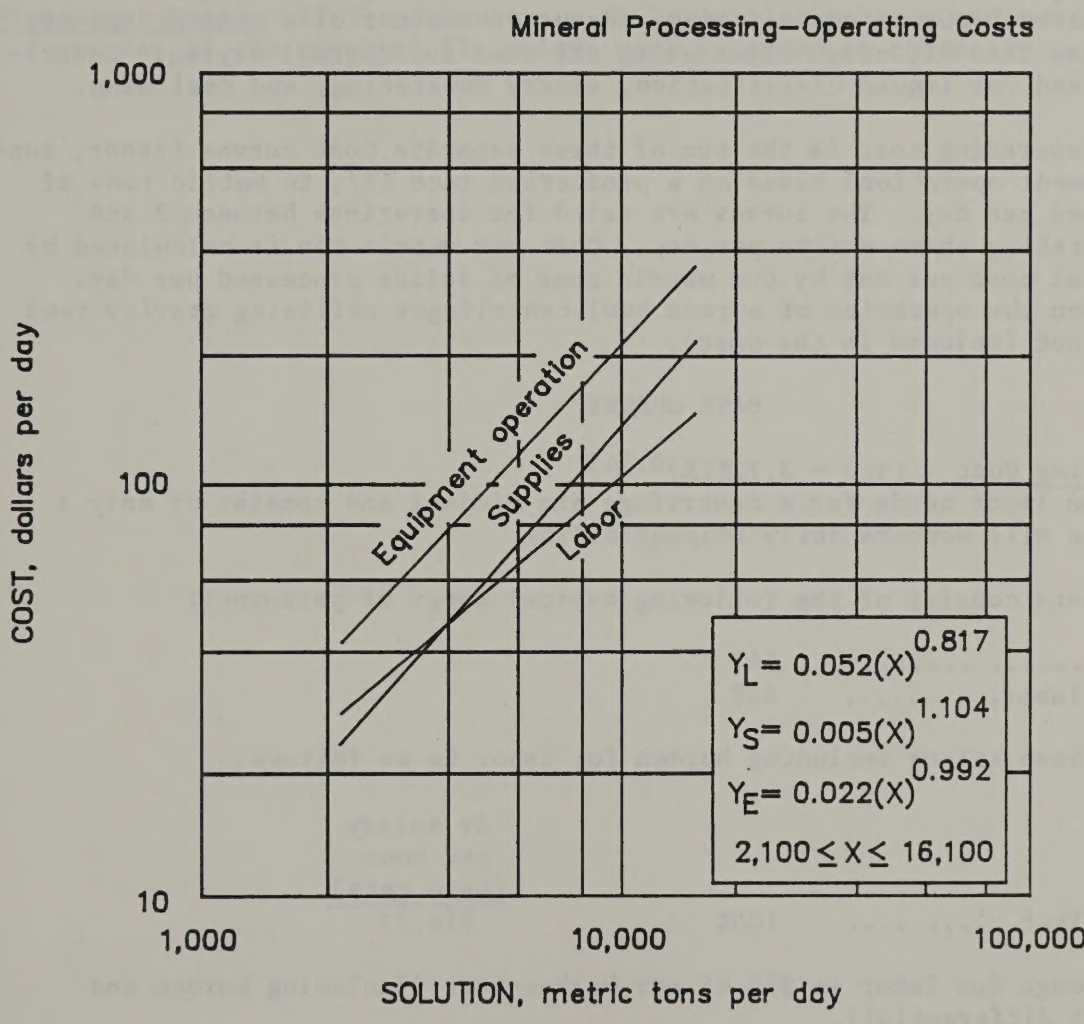
The average base salary including burden for labor is as follows:

		Av Salary per hour (base rate)
Mill operator..............	100%	$16.78

The average wage for labor is $16.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_{S\ PRECOAT}) = 0.005(X)^{1.104}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_{E\ PREÇOAT}) = 0.022(X)^{0.992}$
The equipment operation curve consists of 85% for precoat and 15% for repair parts.



7.1.4.2.3. Concentrate filtration
PRESSURE FILTRATION—PRECOAT

7.1. MINERAL PROCESSING--OPERATING COST

7.1.4. SOLID-LIQUID SEPARATION

7.1.4.2.4. CONCENTRATE FILTRATION
CENTRIFUGAL FILTRATION

The centrifuge filtration curves are based on the use of screen bowl centrifuges for concentrate filtration or tailings dewatering. Screen bowl centrifuges are normally used for feeds without an excess of minus 325-mesh fines. They are considered high-output units noted for their ability to produce a drier product than an equivalent capacity vacuum filter, and have the added advantage of being able to wash the filter cake. During centrifuging, the water content of a concentrate may be reduced to less than 8%, often eliminating the need for thermal drying. Centrifuges can also used for liquid clarification, slurry dewatering, and desliming.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons of dry solids handled per day. The curves are valid for operations between 5 and 30,000 mtpd, operating three shifts per day. Cost per metric ton is calculated by dividing the total cost per day by the metric tons of solids processed per day. Costs are based on the operation of screen bowl centrifuges utilizing gravity feed (feed pumps are not included in the cost).

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 3.728(X)^{0.543}$
The operation labor needs for a centrifuge are minimal and consist of only a fraction of a mill workers daily responsibility.

The labor costs consist of the following typical range of personnel:

Direct labor..............	54%
Maintenance labor..........	46%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Mill floorwalker...........	100%	$16.22

The average wage for labor is $16.45 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.216(X)^{1.010}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 1.366(X)^{0.807}$
The equipment operation curve consists of 83% for maintenance and repair parts (including ceramic hardfacing for scrolls and screens) and 17% for lubrication.

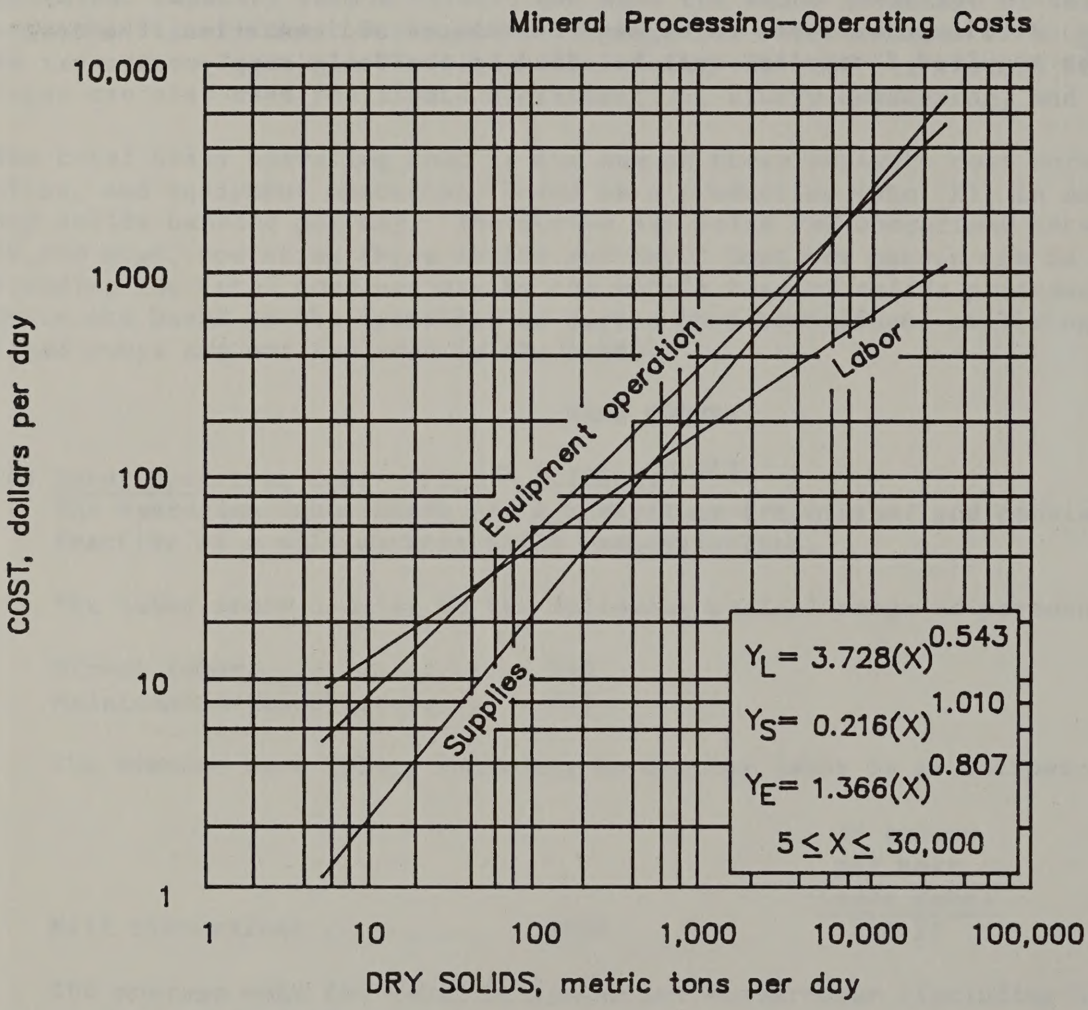
ADJUSTMENT FACTORS

Solid Bowl Centrifuge Factor In situations where water clarification is required, or excessive fines must be dewatered, solid bowl centrifuges are often called for. If solid bowl centrifuges are to be used, multiply the total daily operating costs by the following factor:

Solid bowl centrifuge factor $(F_S) = 0.778$

It must be remembered that solid bowl units are used mostly for clarification and desliming, and that in order to maintain throughput, flocculation of the feed may be required.

Flocculant Factor If flocculants are to be used to enhance sedimentation, the cost per day of the required flocculant must be added to the daily supply cost.



7.1.4.2.4. Concentrate filtration
CENTRIFUGAL FILTRATION

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.4. SOLID-LIQUID SEPARATION

7.1.4.3. CONCENTRATE DRYING

Drying operations generally use natural gas when and if available; otherwise, fuel oil is used. A hypothetical product was used for the cost determinations; it contained 12% moisture (from the filtration section) and was dried to 2% moisture.

The curves are based on an operation using rotary dryers equipped with dust collectors and scrubbers and include conveyors in and out of the dryer. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in metric tons of dry concentrate per day. The curves are valid for operations between 4 and 8,000 mtpd, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_{L\ SMALL}) = 141.199(X)^{0.063}$
$(Y_{L\ LARGE}) = 48.296(X)^{0.237}$

The operating labor costs consist of the following typical range of personnel:

	Small (4 to 400 mtpd)	Large (400 to 8,000 mtpd)
Direct labor...............	36%	33%
Maintenance labor..........	64%	67%

The average base salary including burden for labor is as follows:

	Small (4 to 400 mtpd)	Large (400 to 8,000 mtpd)	Av salary per hour (base rate)
Dryer operator.............	73%	65%	$15.89
Helper.....................	27%	35%	13.66

The average wage for labor is $15.33 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_{S\ SMALL}) = 17.691(X)^{0.634}$
The supply cost consists of 73% natural gas and 27% electric power.

(S) Supply Operating Cost $(Y_{S\ LARGE}) = 3.084(X)^{0.933}$
The supply cost consists of 95% natural gas and 5% electric power.

(E) Equipment Operating Cost $(Y_{E\ SMALL}) = 101.404(X)^{0.065}$
$(Y_{E\ LARGE}) = 28.501(X)^{0.265}$

Equipment operation consists of 94% for repair parts and 6% for lubrication for the dryer drum, drives, fans, conveyors, and dustcollection system for both the small and large operations.

ADJUSTMENT FACTORS

Fuel Oil Factor If fuel oil is used instead of natural gas, multiply the natural gas portion by the following factor:

Fuel oil factor $(F_F) = 2.3$

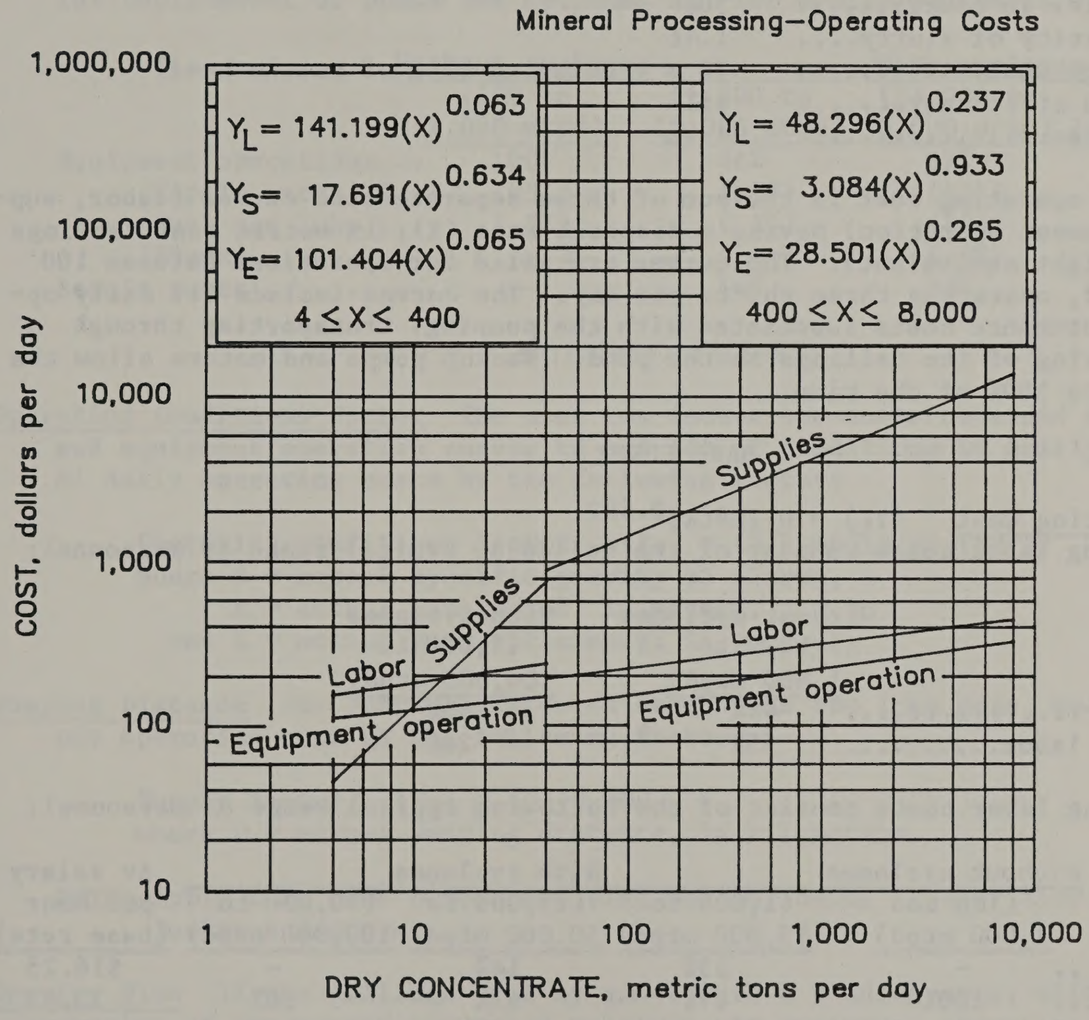
Moisture Factor The cost of gas is a direct function of the amount of moisture to be removed. If the reduction in moisture is different than drying from 12% to 2%, the cost of natural gas should be multiplied by the following factor:

Moisture Factor $(F_M) = 8.624[(C-M)/((1-C)(1-M))]$

where C = input moisture content, expressed as a fraction of the total weight of dryer feed material (including moisture),

and M = output moisture content, expressed as a fraction of the total weight of dryer product material.

Actual costs, unit prices, wages, or cost breakdowns, if known, may be substituted for values given in the above descriptions in order to adjust the labor, supplies, and equipment curves.



7.1.4.3. Concentrate drying

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.4. SOLID-LIQUID SEPARATION

7.1.4.4. TRANSPORT AND PLACE TAILINGS

These curves cover the cost of transporting the partially dewatered tailings to a tailings pond. The tailings dam is raised by the constant addition of new material through the use of cyclones (for mineral processing plants over 1,000 mtpd). The curves are based on the following data:

Percent solids in slurry......	50%
Specific gravity of slurry....	1.46
Total average head............	30 m (including 15 m of static head)
Average pump efficiency.......	65%
Pumping distance..............	1 km

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a disposal rate (X), in metric tons tailings per day (dry weight equivalent). The curves are valid for operations between 100 and 100,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with the pumping, transporting through pipe, and disposing of the tailings in the pond. Backup pumps and motors allow the system to operate 100% of the time.

BASE CURVE

(L) <u>Labor Operating Cost</u> $(Y_L) = 0.728(X)^{0.682}$
The operating labor costs consist of the following typical range of personnel:

	Without cyclones (100 to 1,000 mtpd)	With cyclones (1,000 to 100,000 mtpd)
Direct labor...............	45%	80%
Maintenance labor..........	55%	20%

The operating labor costs consist of the following typical range of personnel:

	Without cyclones	With cyclones			Av salary
	(100 to 1,000 mtpd)	(1,000 to 15,000 mtpd)	(15,000 to 50,000 mtpd)	(50,000 to 100,000 mtpd)	per hour (base rate)
Operator..........	-	53%	14%	-	$16.25
Laborer...........	100%	47%	67%	50%	13.97
Crane operator....	-	-	10%	19%	15.89
Truck driver......	-	-	9%	19%	15.89
Dozer operator....	-	-	-	12%	16.33

Operating costs average $15.05 per hour (including shift differential and burden). Changes in pumping rate, slurry composition (percent solids), or distance do not materially affect the daily average labor wage.

(S) Supply Operating Cost $(Y_S) = 0.110(X)^{0.803}$
The supply cost consists of electric power and steel pipe.

	Without cyclones	With cyclones		
	(100 to 1,000 mtpd)	(1,000 to 15,000 mtpd)	(15,000 to 50,000 mtpd)	(50,000 to 100,000 mtpd)
Power...............	81%	78%	91%	84%
Pipe (steel)........	19%	21%	9%	16%

(E) Equipment Operating Cost $(Y_E) = 0.00261(X)^{1.052}$
The equipment operation curve covers the daily operating cost for pumping, cycloning, and redistributing waste in a tailings pond, and includes allowances for replacement of pumps and cyclones and for mobile equipment operating costs.

	Without cyclones	With cyclones		
	(100 to 1,000 mtpd)	(1,000 to 15,000 mtpd)	(15,000 to 50,000 mtpd)	(50,000 to 100,000 mtpd)
Equipment operation....	100%	46%	67%	88%
(Repair parts)....	(95%)	(95%)	(45%)	(45%)
(Fuel and lube)...	(5%)	(5%)	(52%)	(52%)
(Tires)...........	(-)	(-)	(3%)	(3%)
Repair parts...........	-	54%	33%	12%

ADJUSTMENT FACTORS

Operating Conditions Factor The user can factor the costs obtained from the supply and equipment operation curves to any set of conditions by multiplying the total daily operating costs by the following factor:

Operating conditions factor $(F_C) = (S/1.46)(H/30)(65/E)$
where S = actual specific gravity of slurry,
H = actual total head, in meters,
and E = actual pump efficiency, in percent.

Pumping Distance For pumping distances other than the 1-km base, multiply the supply operating cost by the following factor:

Supply factor $(F_S) = (D)+0.900$
where D = actual pumping distance, in kilometers.

NOTE--Apply this cost before applying the following gravity flow power cost adjustment factors.

Gravity Flow If the tailings flow by gravity to a ponding area, eliminate the power portion of the supply curve and multiply the equipment operating cost by one of the the following factors:

For operations greater than or equal to 100 mtpd and less than or equal to 1,000 mtpd

Equipment operation factor $(F_{E\ 100-1,000}) = 0.0$
This will eliminate the equipment portion of the curve.

For operations larger than 1,000 mtpd and less than or equal to 100,000 mtpd

Equipment operation factor $(F_{E\ 1,000\text{-}100,000}) = 0.8$

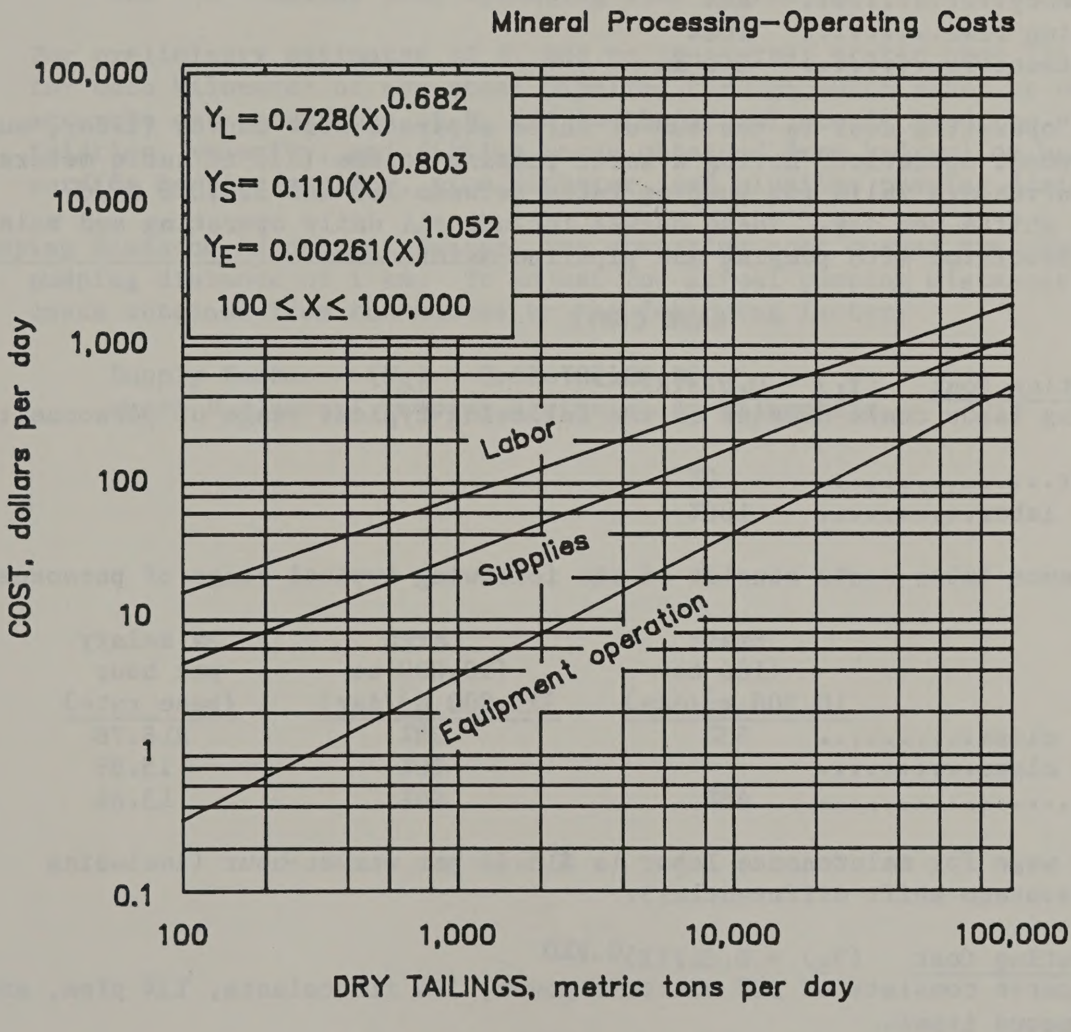
Cyclones If cyclones are not used (applies only to operations greater than 1,000 mtpd), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_{L\ 1,000\text{-}100,000}) = 0.6$

Supply factor $(F_{S\ 1,000\text{-}100,000}) = 0.95$

Equipment operation factor $(F_{E\ 1,000\text{-}100,000}) = 0.6$

Dry Tailings If dry tailings are being transported, use front-end loaders and trucks or surface conveyors for loading and transporting the tailings (see section 3.2.2.6., (IC 9142), or 7.1.7.5.).



7.1.4.4. Transport and place tailings

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.4. SOLID-LIQUID SEPARATION

7.1.4.5. WATER RECLAMATION

These curves cover the cost of returning decanted water from the tailings ponds to the mill. In many cases lime, flocculants, or both may be added to the ponds to settle the colloidal particles. The curves are based on the following data:

Specific gravity of fluid...	1.0
Total head..................	16.5 m
Pump efficiency.............	80%
Pump operating time.........	100%
Pumping distance............	1.0 km

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a water pumping volume (X), in cubic meters per day. The curves are valid for pumping rates between 100 and 325,000 m^3/d, operating three shifts per day. These curves include all daily operating and maintenance costs associated with pumping and pipeline maintenance.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.073(X)^{0.587}$
The operating labor costs consist of the following typical range of personnel:

Direct labor..............	0%
Maintenance labor..........	100%

The maintenance labor costs consist of the following typical range of personnel:

	Small (100 to 10,000 m^3/day)	Large (10,000 to 325,000 m^3/day)	Av salary per hour (base rate)
Mechanic 2d class..........	55%	28%	$16.78
Mechanic 3d class..........	-	26%	15.89
Helper.....................	45%	46%	13.66

The average wage for maintenance labor is $15.44 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.017(X)^{0.910}$
The supply curve consists of 50% electric power, 29% flocculants, 12% pipe, and 9% miscellaneous items.

(E) Equipment Operation Cost $(Y_E) = 0.073(X)^{0.586}$
The equipment operation curve covers the daily cost related to pumping and minor pipeline maintenance, consisting of 96% for parts and 4% for lubrication.

ADJUSTMENT FACTORS

<u>Pumping Head Adjustment Factor</u> The operating cost curves are predicated on a pumping head of 16.5 m. To adjust for actual pumping heads, multiply the costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.450+0.042(H)(S)(E)(T)$

Equipment operation factor $(F_E) = 0.120+0.067(H)(S)(E)(T)$

where H = actual total head (static, friction, velocity, and fittings), in meters,

S = actual specific gravity,

E = actual pump efficiency, expressed as a decimal,

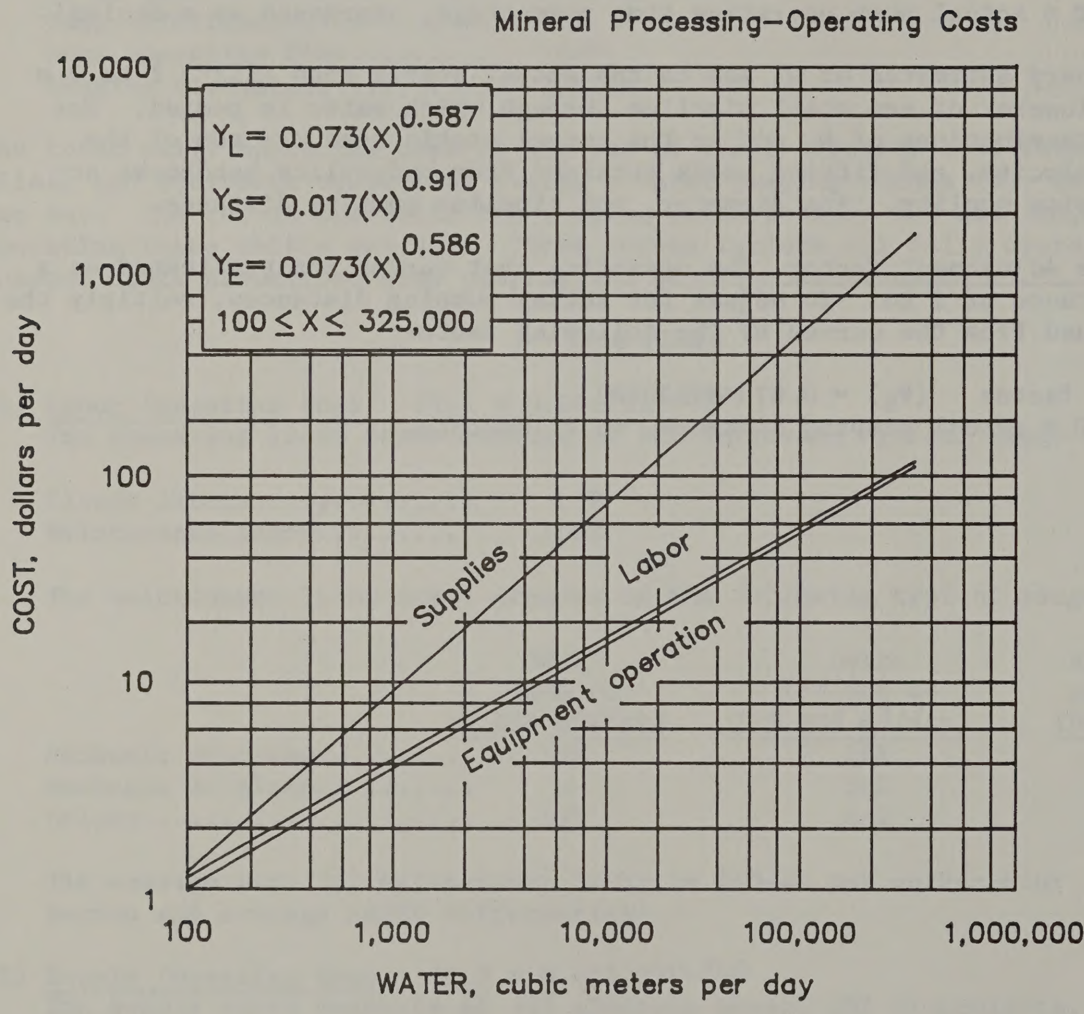
and T = actual pump operating time percentage, expressed as a decimal.

For preliminary estimates of H, add to the actual static head (lift) 1 to 2 m for each kilometer of new steel pipeline through which water is pumped. For accurate determinations of H, add to the actual static head the sum of the friction, velocity, and fitting heads obtained from hydraulics handbooks according to pipe quality, pipe diameter, and pipeline pumping distance.

<u>Pumping Distance Adjustment Factor</u> The operating cost curves are predicated on a pumping distance of 1 km. To adjust for actual pumping distances, multiply the costs obtained from the curves by the following factor:

Supply factor $(F_S) = 0.870+0.130(D)$

where D = actual pumping distance, in kilometers.



7.1.4.5. Water reclamation

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.5. HYDROMETALLURGY

7.1.5.1.1. ACID LEACHING BERYLLIUM ORE

The operating cost curves for beryllium ore include the operation and maintenance of the leaching circuit from the ore to the leaching circuit through the discharge of the leached ore. The total daily operating cost is the sum of three separate cost curves for labor, supplies, and equipment operation at a daily feed rate (X) in metric tons of ore per day. The curves are valid for operations between 85 and 560 mtpd, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $Y_L = 7.348(X)^{0.427}$
The labor costs consist of the following typical range of personnel:

Direct labor...............	95%
Maintenance labor..........	5%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Mill operator..............	66%	$16.78
Mill helper................	26%	13.66
Mill laborer...............	8%	11.68

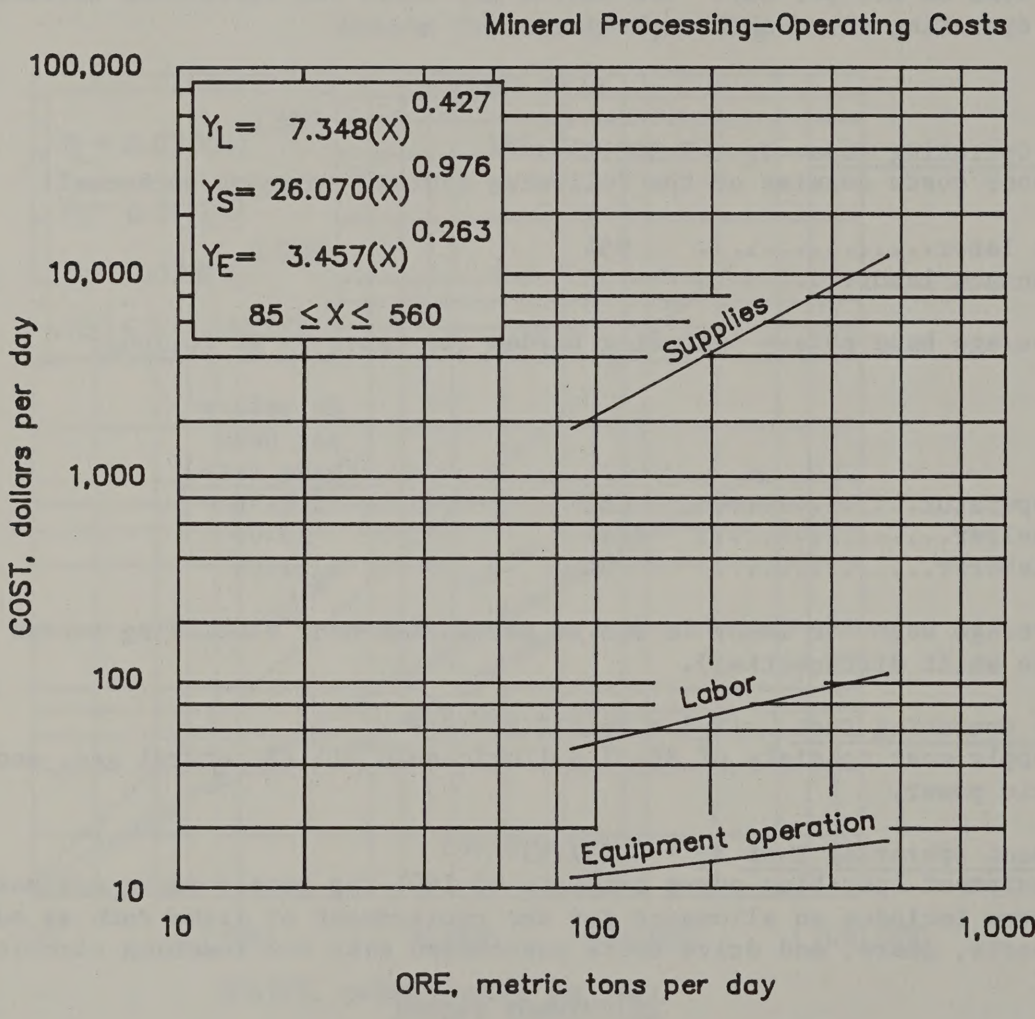
The average wage for labor is $15.64 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 26.070(X)^{0.976}$
The supply cost consists of 86.5% sulfuric acid, 11.6% natural gas, and 1.9% electric power.

(E) Equipment Operating Cost $Y_E = 3.457(X)^{0.263}$
The equipment operating curve consists of 100% for repair parts and materials. The curve includes an allowance for the replacement of items such as motors, pump parts, gears, and drive belts associated with the leaching circuit.

ADJUSTMENT FACTOR

Shift Factor The base curves are based on a three-shift-per-day leaching operation. Beryllium leaching operations would probably operate on continuous basis to maintain a steady feed to the subsequent separation circuit. No adjustment factor for a oneor two-shift operation is recommended for acid leaching of beryllium ores.



7.1.5.1.1. Acid leaching
BERYLLIUM ORE

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.5. HYDROMETALLURGY

7.1.5.1.2. ACID LEACHING CARBONATE

The operating cost curves for leaching carbonates in concentrates include the operation and maintenance of the leaching circuit from the concentrate to the leaching circuit through the discharge of the leached concentrate. The total daily operating cost is the sum of three separate cost curves for labor, supplies, and equipment operation at a daily feed rate (X) in metric tons of concentrate per day. The curves are valid for operations between 4 and 1,700 mtpd, operating three shifts per day.

BASE CURVE

The base curves for leaching carbonates in concentrates were assumed at 5% carbonate (as CO_3).

(L) Labor Operating Cost $(Y_L) = 5.100(X)^{0.470}$
The labor costs consist of the following typical range of personnel:

Direct labor...............	78%
Maintenance labor..........	22%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator......	8%	$17.23
Mill operator.............	50%	16.78
Mill helper................	32%	13.66
Mill laborer...............	10%	11.68

The average wage for labor is $15.69 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 4.974(X)^{0.966}$
The supply cost consists of 93.3% sulfuric acid and 6.7% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.622(X)^{0.441}$
The equipment operation curve consists 100% for repair parts and materials. The curve includes an allowance for the replacemnt of items such as gears, pump parts, motors, and drive belts associated with the leaching circuit.

ADJUSTMENT FACTORS

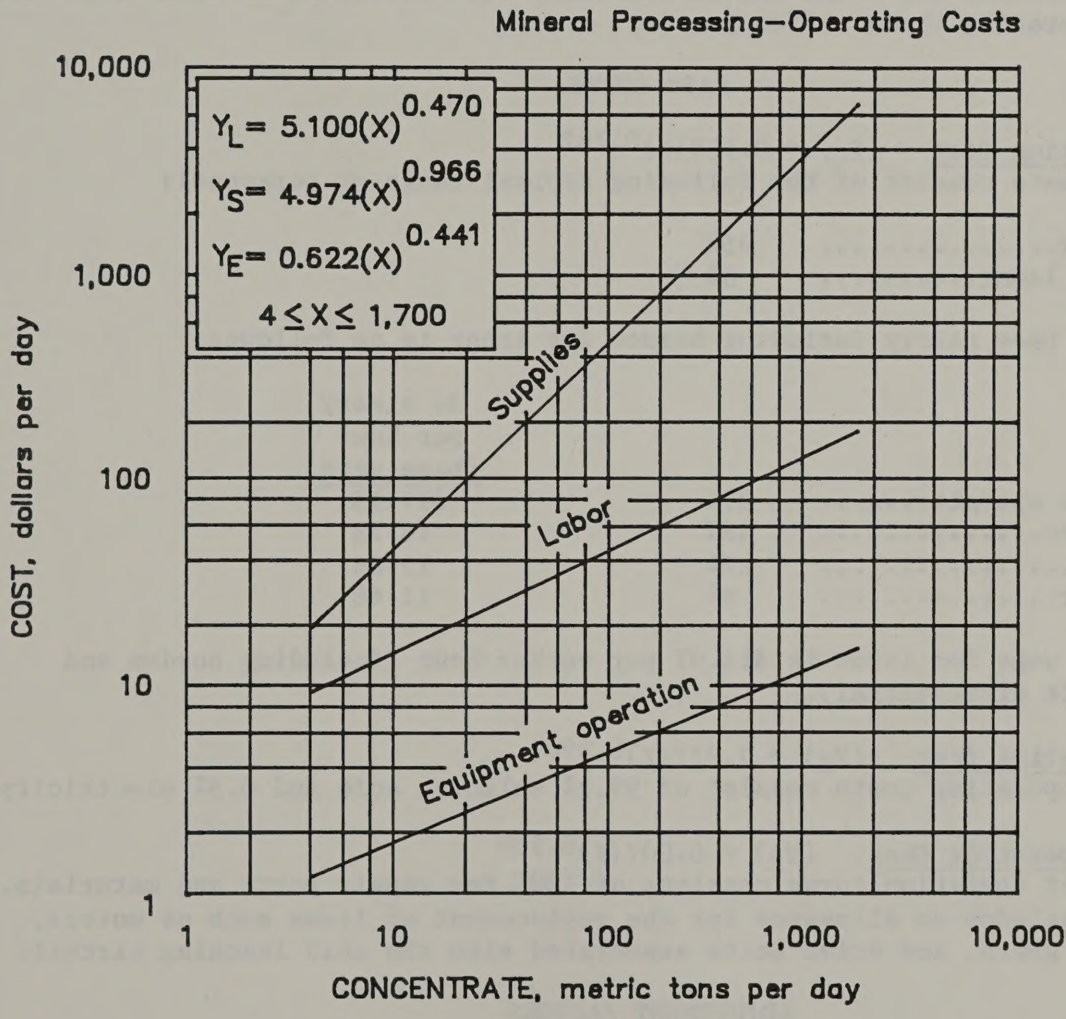
Percent Carbonate Factor The curves are based on a carbonate content (as CO_3) of 5% in the concentrate. To adjust the base curve for different levels of carbonate content, multiply the cost obtained from the supply curve by the following factor:

Supply factor $(F_S) = 0.195(C)+0.0257$
where C = carbonate as CO_3 in the concentrate, expressed as percent.

Leach Time Factor The curves are based on a leaching time of 4 h. To adjust the base curve for different leach times, multiply the costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.007(T)+0.972$

Equipment operation factor $(F_E) = 0.370(T)^{0.717}$
where T = actual leach time, in hours.



7.1.5.1.2. Acid leaching
CARBONATE

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.5. HYDROMETALLURGY

7.1.5.1.3. ACID LEACHING
COPPER ORE

The operating cost curves for copper ore include the operation and maintenance of the leaching circuit from the ore to the leaching circuit through the discharge of the leached ore. The total daily operating cost is the sum of three separate cost curves for labor, supplies, and equipment operation at a daily feed rate (X), in metric tons of ore per day. The curves are valid for operations between 3,000 and 10,500 mtpd, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.189(X)^{0.762}$
The labor costs consist of the following typical range of personnel:

Direct labor...............	95%
Maintenance labor..........	5%

The average base salary including burden for labor is as follows:

		Av slaary per hour (base rate)
Control room operator......	29%	$17.23
Mill operator..............	46%	16.78
Mill helper................	17%	13.66
Mill laborer...............	8%	11.68

The average wage for labor is $16.07 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 7.977(X)^{0.998}$
The supply operating costs consist of 99.2% sulfuric acid and 0.8% electricity.

(E) Equipment Operating Cost $(Y_E) = 0.007(X)^{0.999}$
The equipment operation curve consists of 100% for repair parts and materials. The curve includes an allowance for the replacement of items such as motors, pump parts, gears, and drive belts associated with the acid leaching circuit.

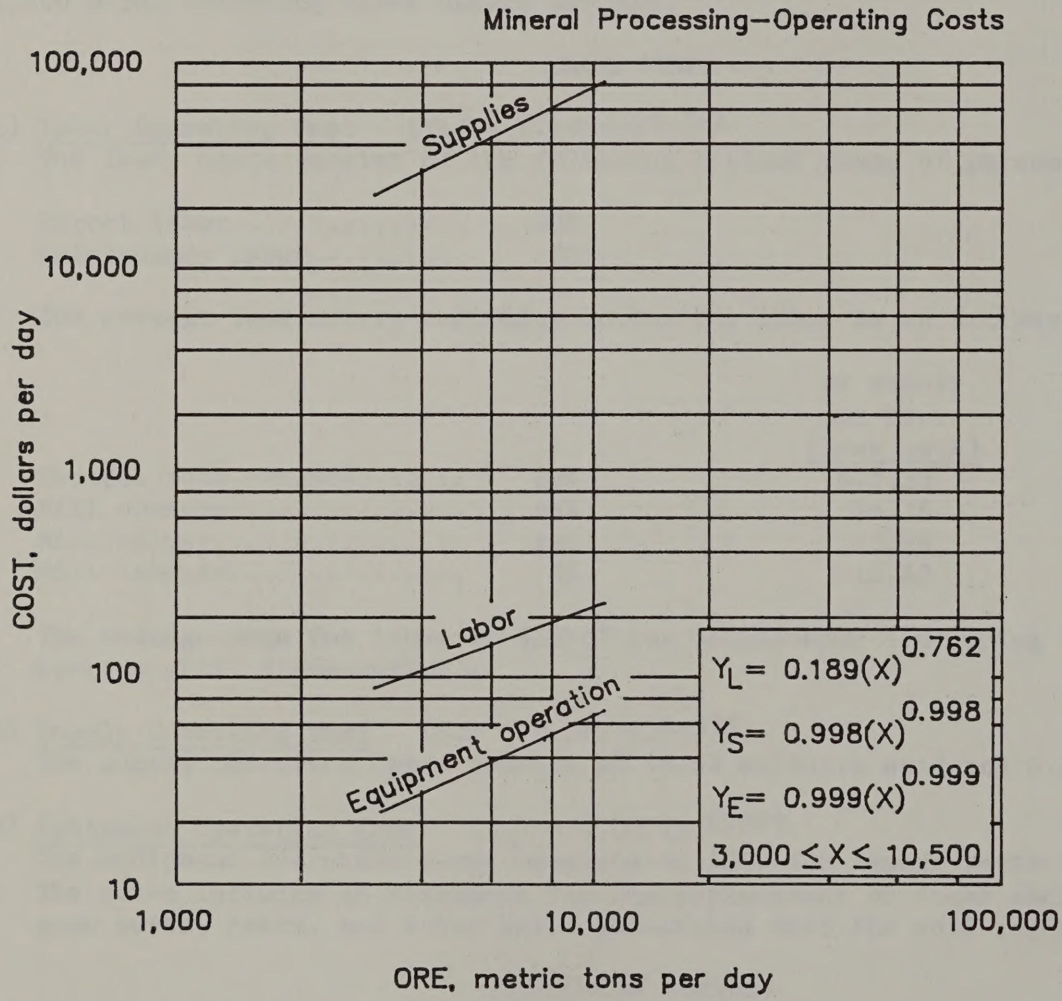
ADJUSTMENT FACTORS

Shift Factor The base curves are based on a three-shift-per-day operation. Copper leaching operations would probably operate on a continuous basis to maintain a steady flow rate to the subsequent countercurrent decantation (CCD) thickening circuit. No adjustment factor for a oneor two-shift operation is recommended for acid leaching of copper ores.

<u>Sulfuric Acid Consumption Factor</u> The base curve is based on an acid consumption rate of 220 lb of sulfuric acid per metric ton of copper ore leached. For consumption rates other than 220 lb, multiply the cost obtained from the supply curve by the following factor:

Supply factor $(F_S) = 0.0045(X)+0.010$

where X = actual consumption rate of sulfuric acid, in pounds per metric ton of copper ore leached.



7.1.5.1.3. Acid leaching
COPPER ORE

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.5. HYDROMETALLURGY

7.1.5.1.4. ACID LEACHING PYROCHLORE

The operating cost curves for pyrochlore concentrates include the operation and maintenance of the leaching circuit from the concentrate to the leaching circuit through the discharge of the leached concentrate. The total daily operating cost is the sum of three separate cost curves for labor, supplies, and equipment operation at a daily feed rate (X) in metric tons of concentrate per day. The curves are valid for operations between 4 and 170 mtpd, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 5.118(X)^{0.654}$
The labor costs consist of the following typical range of personnel:

Direct labor...............	90%
Maintenance labor..........	10%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Mill operator.............	47%	$16.78
Mill helper...............	53%	13.66

The average wage for labor is $15.32 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 17.656(X)^{0.990}$
The supply cost consists of 93.7% hydrochloric acid, 4.6% filter aid, and 1.7% electric power.

(E) Equipment Operating Cost $(Y_E) = 2.877(X)^{0.494}$
The equipment operation curve consists of 100% for repair parts and materials. The curve includes an allowance for the replacement of items such as motors, pump parts, gears, filter cloth, and drive belts associated with the leaching circuit.

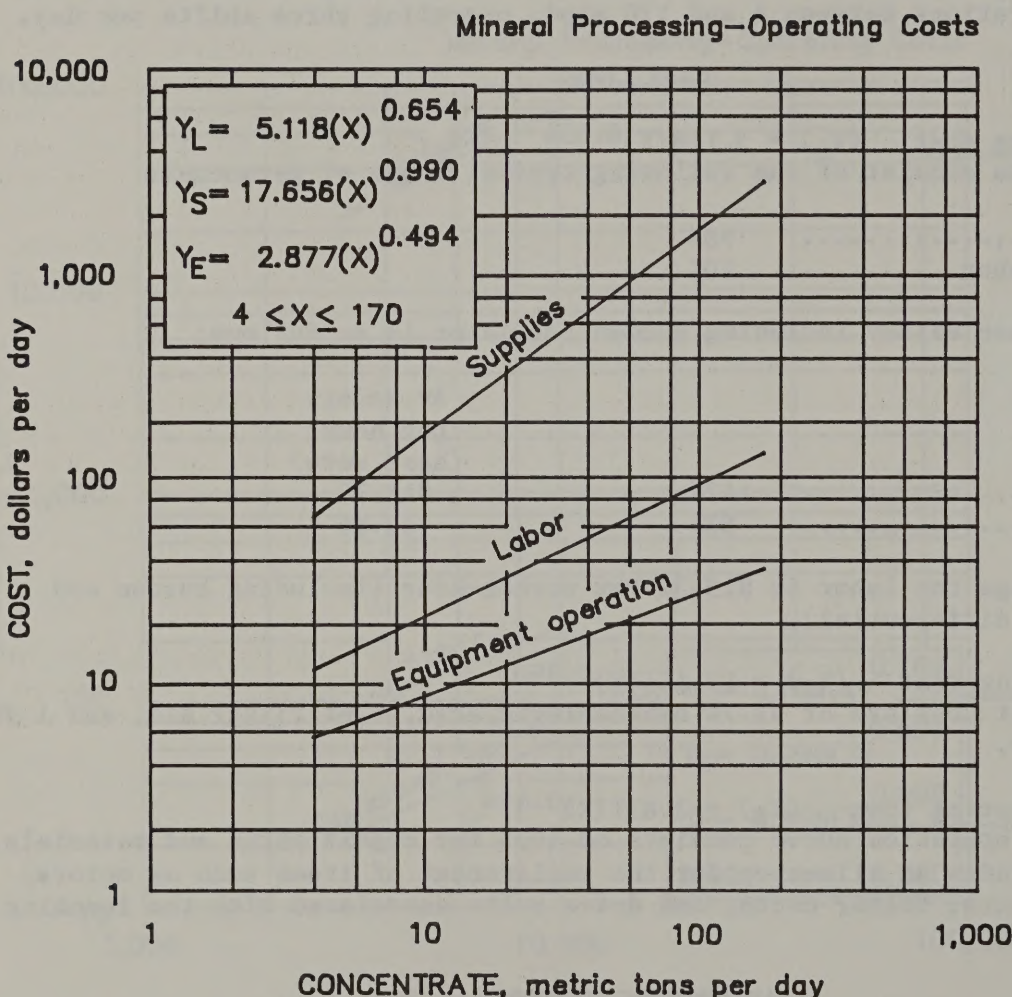
ADJUSTMENT FACTORS

Number of Leaching Stages The curve is based on a two-stage pyrochlore leaching operation. To adjust for a one-stage pyrochlore leach circuit, the costs obtained from the curves should be multiplied by the following factors:

Labor factor $(F_L) = 3.55$

Supply factor $(F_S) = 0.19$

Equipment operation factor $(F_E) = 0.49$



7.1.5.1.4. Acid leaching
PYROCHLORE

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.5. HYDROMETALLURGY

7.1.5.1.5. LEACHING CARBON-IN-PULP

The operational cost curves pertain to carbon-in-pulp (CIP) processing of "lower grade" ores containing approximately 0.09 to 0.7 tr oz of gold per short ton (3 to 24 g of gold per metric ton), 1 troy ounce of silver or gold plus silver per ton (34 g/mt). The section includes all daily operating and maintenance costs for the successive unit processes of conventional slurry thickening of 80% minus 200-mesh ground ore; cyanide agitation leaching; wood-chip and trash screening; adsorption of precious metals by activated coconut carbon in five adsorption stages for gold recovery (six to eight for silver); countercurrent carbon transfer; screening for separation of charcoal from pulp; hot caustic-cyanide stripping of carbon at atmospheric pressure, or a higher pressures with or without the use of alcohol; carbon acid washing and regeneration by heating and quenching; electrowinning on steelwool cathodes; carbon column scavenger recovery from bleed streams and tailing return water used in the process; and bullion refining and casting facilities, including slag processing. Cyanide is not regenerated from the barren solution in the process, and comminution and tailings disposal costs are not included.

The curves are not applicable to conventional cyanide agitation leaching with Merrill-Crowe precipitation; preagglomeration of ores; carbon-in-leach; preoxidation of carbonaceous or graphitic ores; carbon-in-column; autoclave or pressure leaching; amalgamation; high-intensity leaching circuitry; vat, heap or dump leaching; or leaching with lixiviants other than cyanide, such as thiourea, thiosulfate, or aqueous chlorine.

BASE CURVES

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the feed rate (X), in metric tons of ore per day determined on a dry basis. The curves are valid for operations between 300 and 2,200 mtpd of dry circuit feed, operating three shifts per day.

(L) <u>Labor Operating Cost</u> $(Y_L) = 14.002(X)^{0.617}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...............	87%
Maintenance labor..........	13%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator......	45%	$17.56
Mill operator..............	44%	17.11
Helpe......................	11%	13.66

The average wage for labor is \$16.81 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.376(X)+929.089$
The supply cost consists of 52% electric power, 48% reagents Operating cost for supplies includes the reagents and power required for all thickening, leaching, filtering, carbon handling and treatment, carbon scavenging units, and bullion casting facilities.

(E) Equipment Operating Cost $(Y_E) = 3.901(X)^{0.571}$
The equipment operation curve consists of 91% for repair parts and 9% for lubrication.

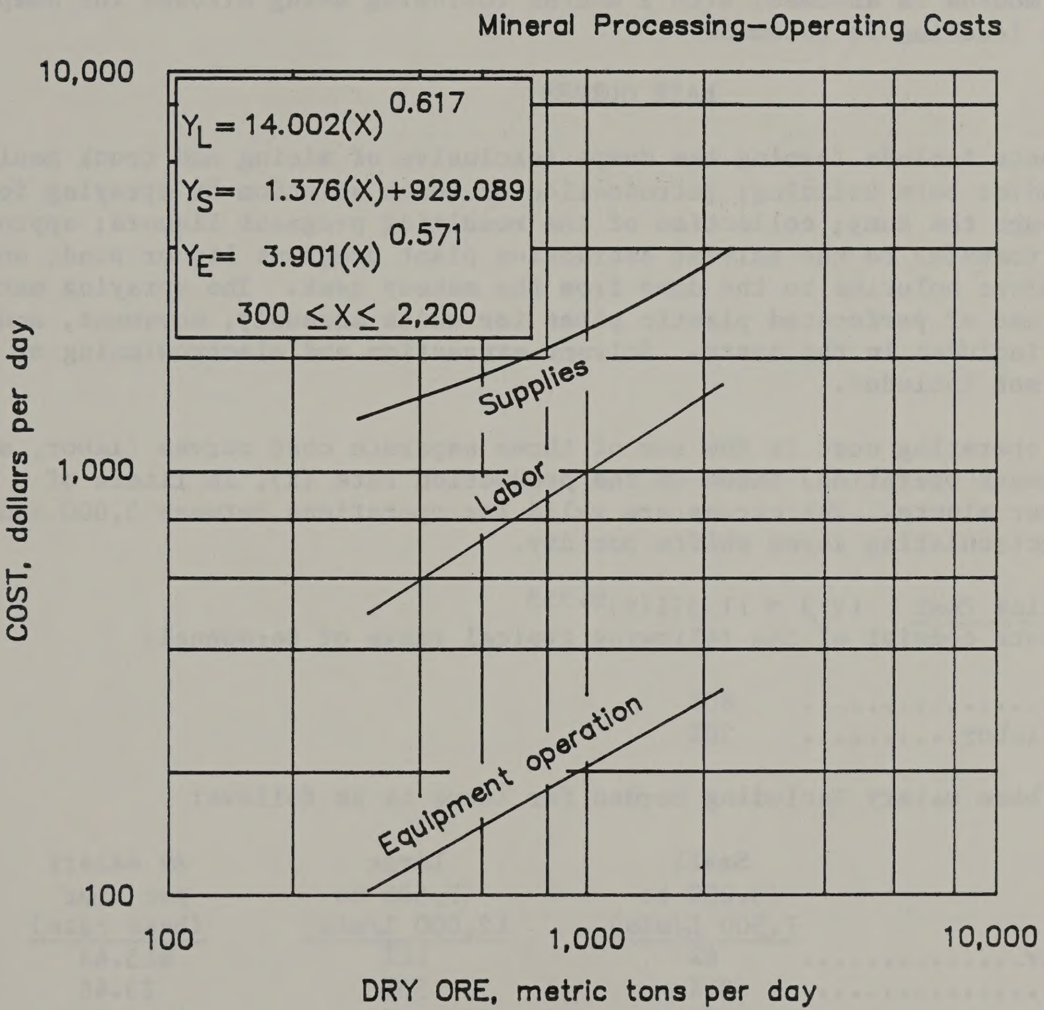
ADJUSTMENT FACTORS

Water Adjustment The hydrometallurgical nature of the leach process requires large quantities of fresh and/or recycled water. The operating costs in this section do not include water costs or costs associated with reclamation of water from tailings ponds. An average requirement of 2.05 m^3 of water per metric ton of ore can be assumed for this process with up to 35% of the requirement being provided through reclamation (section 6.1.4.5.).

Carbonaceous or Graphitic Ores Factor If carbonaceous or graphitic ores are processed, multiply the the costs obtained from the supply curve by the following factor:

Supply factor $(F_S) = 2.6$

This adjustment accounts for the added cost of chlorine (\$206/mt) and soda ash (\$110/mt) required for oxidation.



7.1.5.1.5. Leaching
CARBON–IN–PULP

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.5. HYDROMETALLURGY

7.1.5.1.6. LEACHING COPPER DUMP

Trickle-sprayleaching is the dump leaching methodology applicable for copper ore containing at least 5% pyrite (which generates most of the acid used for maintaining pH). Dump liquors are assumed to range between 0.8 and 2.0 g copper per liter. Dumps are assumed built on the existing topography with no liners being used. A leach time of 6 months is assumed, with 2 months following being allowed for dump "resting" before leaching is resumed.

BASE CURVES

The operating costs include forming the dumps (exclusive of mining and truck haulage); ripping and/or berm building; introduction of leach solution by spraying for percolation through the dump; collection of the resulting pregnant liquors; approximately 3,000-m transfer to the solvent extraction plant pregnant liquor pond; and return of the barren solution to the dump from the makeup tank. The spraying method involves the use of perforated plastic pipes for which assembly, movement, and maintenance are included in the costs. Solvent extraction and electrowinning or cementation are not included.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the production rate (X), in liters of leach solution per minute. The curves are valid for operations between 3,000 and 12,000 L/min, recirculating three shifts per day.

(L) <u>Labor Operating Cost</u> $(Y_L) = 11.371(X)^{0.353}$
The labor costs consist of the following typical range of personnel:

Direct labor...............	80%
Maintenance labor..........	20%

The average base salary including burden for labor is as follows:

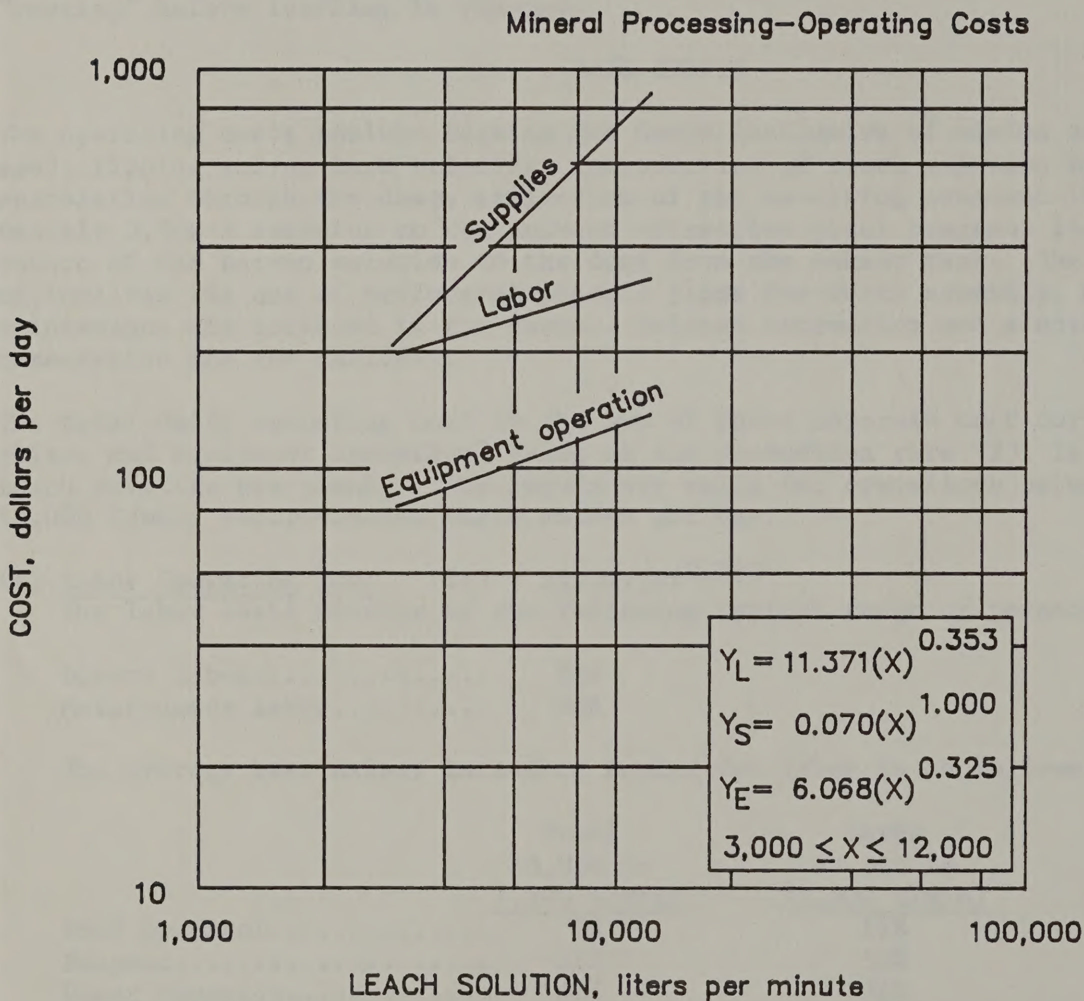
	Small (3,000 to 7,500 L/min)	Large (7,500 to 12,000 L/min)	Av salary per hour (base rate)
Pond operator.............	6%	11%	$15.44
Pumpman....................	31%	53%	23.46
Dozer operator............	63%	36%	16.33

The average wage for labor is $18.55 per worker-hour (including burden and average shift differential).

Maintenance and repair are performed by the dump crew. Labor is assigned only to the day shift.

(S) <u>Supply Operating Cost</u> $(Y_S) = 0.070(X)^{1.000}$
The supply cost consists of 56% electric power, 38% reagents (sulfuric acid), and 6% miscellaneous, which includes replacement pipes and couplings.

(E) <u>Equipment Operating Cost</u> $(Y_E) = 6.068(X)^{0.325}$
The equipment operation curve consists of 60% for parts, 33% for fuel, and 7% for lubrication for pumps, motors, vehicles, and tires.



7.1.5.1.6. Leaching
COPPER DUMP

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.5. HYDROMETALLURGY

7.1.5.1.7. LEACHING
CONVENTIONAL CYANIDE LEACHING WITH MERRILL-CROWE PRECIPITATION

The operational cost curves pertain to conventional cyanide leaching of "higher grade" ores containing greater than 0.7 tr oz of gold or gold plus silver per short ton (24 g/mt) or 1 tr oz of silver per short ton (34 g/mt) and small operations including leaching of flotation and/or gravity concentrates. The section includes all daily operating and maintenance costs for the successive unit processes necessary for cyanide agitation leaching of 80% minus 200-mesh ground ore; dewatering by countercurrent decantation or filtration or a filter-wash-repulp circuit to produce a clear liquor and barren solids; pregnant solution holding; pregnant solution final pressure clarification; liquor vacuum deaeration; Merrill-Crowe zinc precipitation; precious metal filtration; carbon column scavenger recovery from bleed streams and tailings return water; acid pretreatment of precipitates; and bullion refining and casting facilities. Comminution and tailings disposal costs are not included.

The curves cannot be utilized for carbon-in-pulp; preagglomeration of ores; carbon-in-leach; preoxidation of carbonaceous or graphitic ores; carbon-in-column; vat, heap, or dump leaching; autoclave or pressure leaching; amalgamation; highintensity leaching circuitry; or leaching with lixiviants other than cyanide, such as with thiourea, thiosulfate, or aqueous chlorine.

BASE CURVES

The total daily operating cost is the sum of the labor, supplies, and equipment operation cost curves, each of which is based on the feed rate (X), in metric tons ore per day determined on a dry basis. The curves are valid for operations between 5 and 2,800 mtpd of circuit feed, operating 3 shifts per day.

(L) <u>Labor Operating Cost</u> $(Y_L) = 378.543(X)^{0.247}$
The operating labor costs consist of the following typical range of personnel:

	Small (5 to 50 mtpd)	Large (50 to 2,800 mtpd)
Direct labor...............	80%	72%
Maintenance labor..........	20%	28%

The average base salary including burden for labor is as follows:

	Small (5 to 50 mtpd)	Large (50 to 2,800 mtpd)	Av salary per hour (base rate)
Mill operator..............	49%	45%	$16.78
Control room operator......	51%	-	17.56
Helper.....................	-	13	13.66
Dryer filter operator......	-	42%	16.22

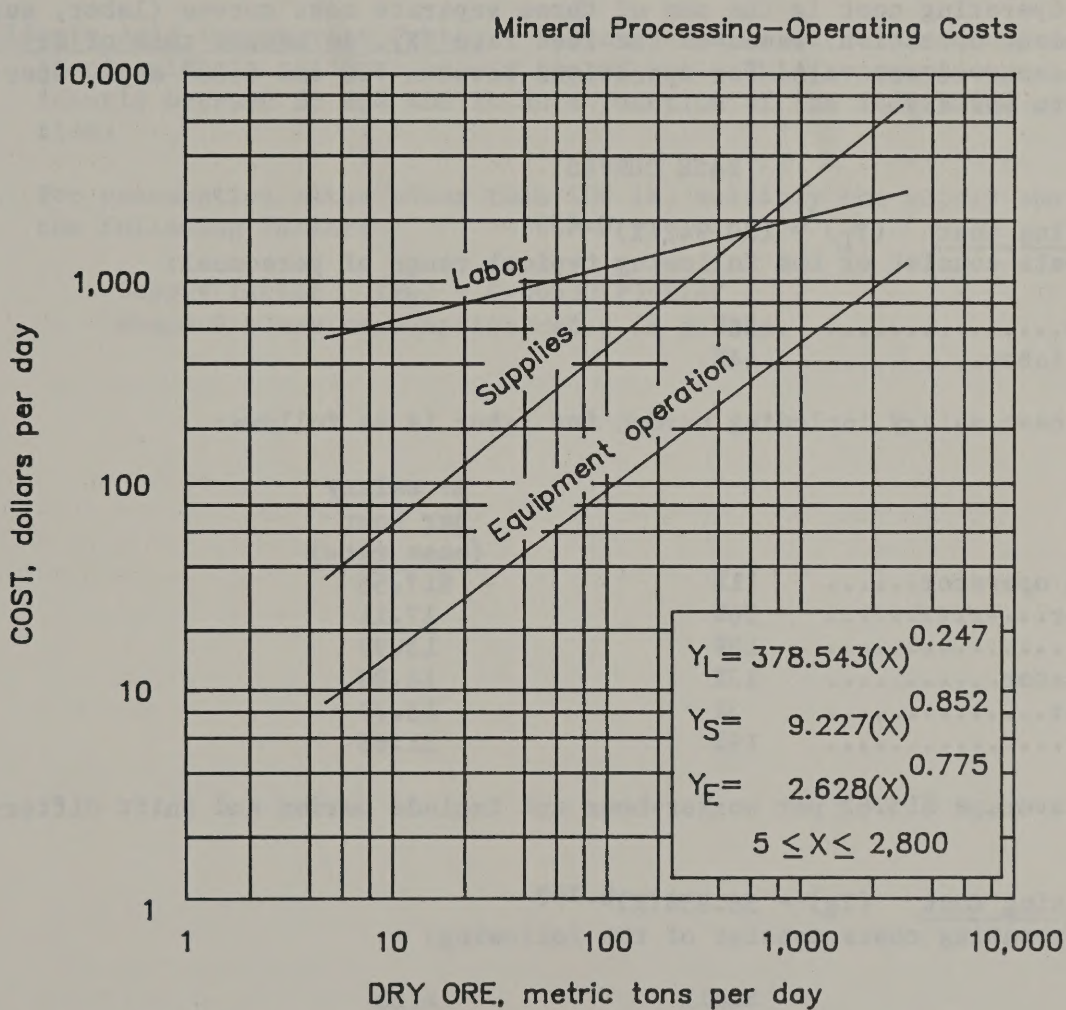
The average wage for labor for a small operation is $17.87 per worker-hour and for a large operation is $17.18 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 9.227(X)^{0.852}$
The operating cost for supplies includes the reagents and power required for all thickening, leaching, filtering, precipitation, carbon column scavenging, and bullion casting facilities. For small operations, the supply cost consists of 75% electric power and 25% reagents. For large mills, the supply cost consists of 71% to 85% reagents and 15% to 29% electric power.

(E) Equipment Operating Costs $(Y_E) = 2.628(X)^{0.775}$
The equipment operation curve consists of 93% for repair parts and 7% for lubrication.

ADJUSTMENT FACTOR

Water Adjustment The hydrometallurgical nature of the leach process requires large quantities of fresh and/or recycled water. The base curve costs do not include water costs or costs associated with reclamation of water from tailings ponds. An average requirement of 1.13 m^3 of water per metric ton of ore can be assumed for this process.



7.1.5.1.7. Leaching
CONVENTIONAL CYANIDE LEACHING WITH
MERRILL—CROWE PRECIPITATION

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.5. HYDROMETALLURGY

7.1.5.1.8. LEACHING URANIUM

The operating cost curves for uranium leaching include the operation and maintenance of a uranium leaching operation from the ground slurry storage tanks following grinding through the production of uranium concentrate, yellowcake. The unit process includes leaching, solvent extraction, precipitation, and drying circuits. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the feed rate (X), in metric tons of dry ore per day. The curves are valid for operations between 770 and 6,300 mtpd, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 180.942(X)^{0.459}$

The labor costs consist of the following typical range of personnel:

Direct labor...............	56%
Maintenance labor..........	44%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator......	11%	$17.56
Mill operator..............	36%	17.11
Mill helper................	18%	13.99
Mill suboperator...........	13%	14.89
Packer-loader..............	3%	15.77
Mill laborer...............	19%	11.68

Labor costs average $15.62 per worker-hour and include burden and shift differentials.

(S) Supply Operating Cost $(Y_S) = 36.954(X)^{0.792}$

The supply operating costs consist of the following:

	Small (770 to 2,000 mtpd)	Large (2,000 to 6,300 mtpd)
Sulfuric acid.........	38.6%	54.2%
Other reagents........	17.8%	25.0%
Electric power........	5.5%	4.9%
Fuel..................	38.1%	15.9%

(E) Equipment Operating Cost $(Y_E) = 20.742(X)^{0.649}$
The equipment operation curve consists of 99.6% for repair parts and materials and 0.4% for lubrication. The curve includes an allowance for the replacement of items such as motors, pump parts, gears, and drive belts associated with uranium processing circuits.

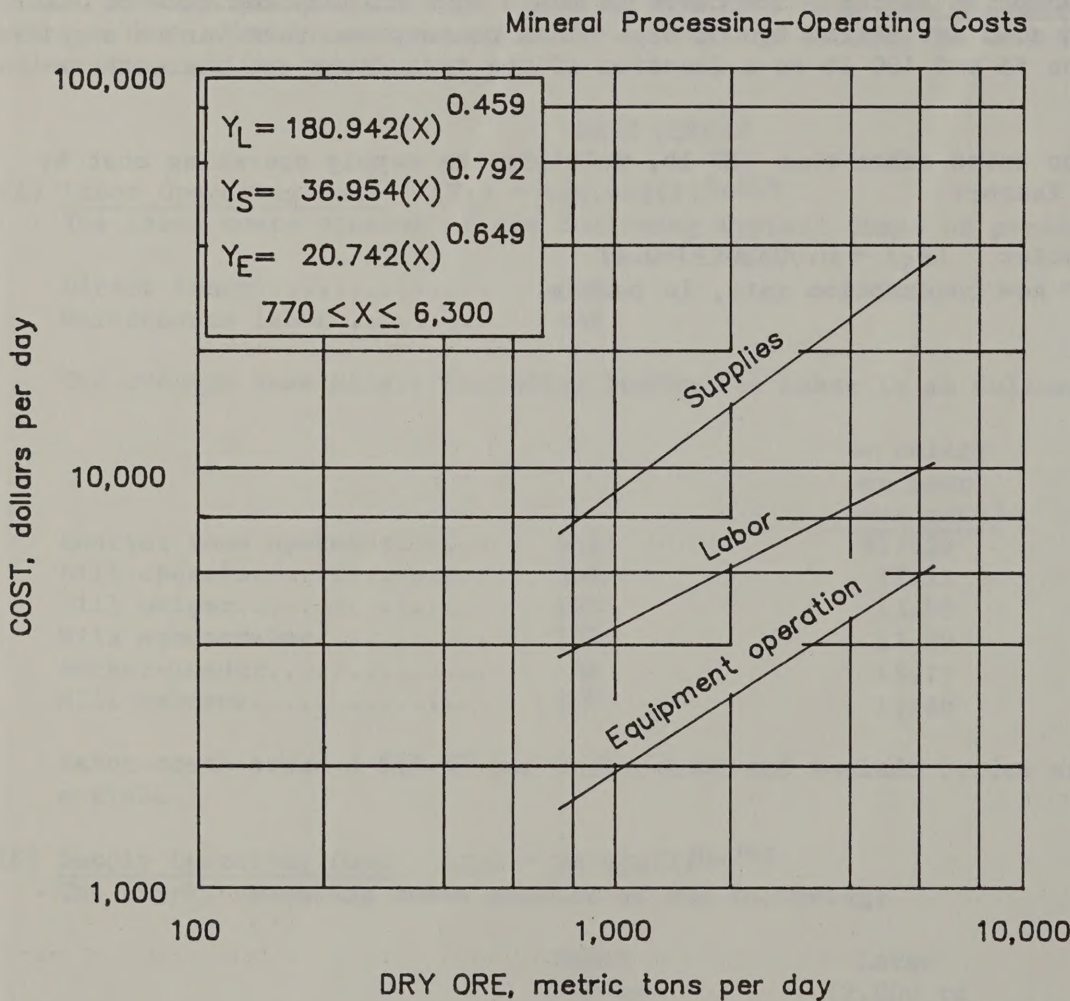
ADJUSTMENT FACTORS

Shift Factor The curve is based on a three-shift-per-day operation. Typically, uranium leaching operations operate on a continuous basis to maintain steady flow rates between the various processing circuits. No adjustment factor for a one- or two-shift operation is recommended for this unit process.

Sulfuric Acid Consumption Factor The curve is based on a consumption rate of 100 lb of sulfuric acid per metric ton of ore. This consumption rate varies significantly between 55 and 400 lb as a function of the individual ore characteristics.

For consumption rates other than 100 lb, multiply the supply operating cost by the following factor:

Supply factor $(F_S) = 0.00530(P)+0.47$
where P = new consumption rate, in pounds.



7.1.5.1.8. Leaching
URANIUM

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.5. HYDROMETALLURGY

7.1.5.2.1. SOLVENT EXTRACTION BERYLLIUM

The operating cost curves for a beryllium solvent extraction circuit include its operation and maintenance from clarified pregnant aqueous solution through the production of a pregnant strip solution. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the feed rate (X), in liters per minute of clarified pregnant aqueous solution to the solvent extraction circuit. The curves are valid for operations between 85 and 575 L, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 34.627(X)^{0.452}$
The labor costs consist of the following typical range of personnel:

Direct labor...............	90%
Maintenance labor..........	10%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Solvent extraction operator..	74%	\$16.78
Solvent extraction helper....	19%	13.66
Laborer......................	7%	11.68

The average wage for labor is \$15.94 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 5.662(X)^{0.980}$
The supply operating cost consists of 81.8% reagents, 13.6% natural gas, and 4.6% electricity.

(E) Equipment Operating Cost $(Y_E) = 4.929(X)^{0.186}$
The equipment operation curve consists of 100% for repair parts and materials. The curve includes an allowance for the replacement of items such as motors, pump parts, bearings, and drive belts associated with the beryllium solvent extraction circuit.

ADJUSTMENT FACTORS

<u>Shift Factor</u> The base curves are based on a three-shift-per-day operation. It is desirable to operate solvent extraction circuits on a continuous basis to minimize the formation of crud and/or emulsions. The crud and/or emulsions may contain radioactive materials and would require special disposal and/or processing at an additional cost. No adjustment factor for a oneor two-shift operation is recommended for beryllium solvent extraction circuits.

<u>Number of Extraction Stages</u> The base curves are premised on the installation of seven extraction stages. To adjust for a different number of extraction stages, multiply the supply and equipment operation costs obtained from the curves by the following factors:

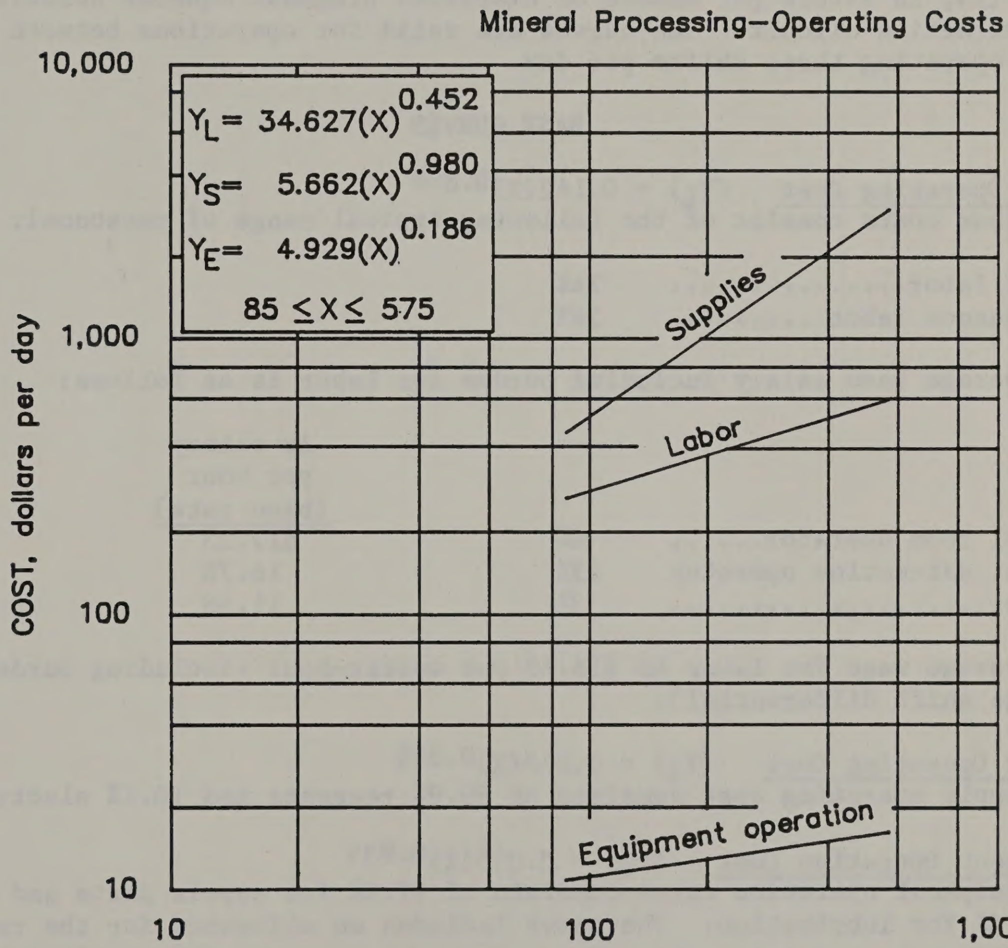
Supply factor $(F_S) = 0.958(N)^{0.022}$

Equipment operation factor $(F_E) = 0.527(N)^{0.329}$
where N = number of extraction stages.

<u>Number of Stripping Stages</u> The base curves are premised on the installation of two stripping stages. To adjust for a different number of stripping stages, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.998(S)^{0.003}$

Equipment operation factor $(F_E) = 0.940(S)^{0.090}$
where S = number of stripping stages.



7.1.5.2.1. Solvent extraction
BERYLLIUM

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.5. HYDROMETALLURGY

7.1.5.2.2. SOLVENT EXTRACTION COPPER

The operating cost curves for a copper solvent extraction circuit include its operation and maintenance from clarified pregnant aqueous solution through the production of a pregnant strip solution. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the feed rate (X), in liters per minute of clarified pregnant aqueous solution to the solvent extraction circuit. The curves are valid for operations between 8,000 and 27,000 L, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 0.142(X)^{0.899}$
The labor costs consist of the following typical range of personnel:

Direct labor...............	74%
Maintenance labor..........	26%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator......	4%	$17.23
Solvent extraction operator	93%	16.78
Laborer....................	3%	11.68

The average wage for labor is $16.69 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.277(X)^{0.988}$
The supply operating cost consists of 89.9% reagents and 10.1% electricity.

(E) Equipment Operation Cost $(Y_E) = 0.020(X)^{0.935}$
The equipment operation curve consists of 97.6% for repair parts and materials and 2.4% for lubrication. The curve includes an allowance for the replacement of items such as motors, pump parts, bearings, gears, piping, and drive belts associated with the copper extraction circuit.

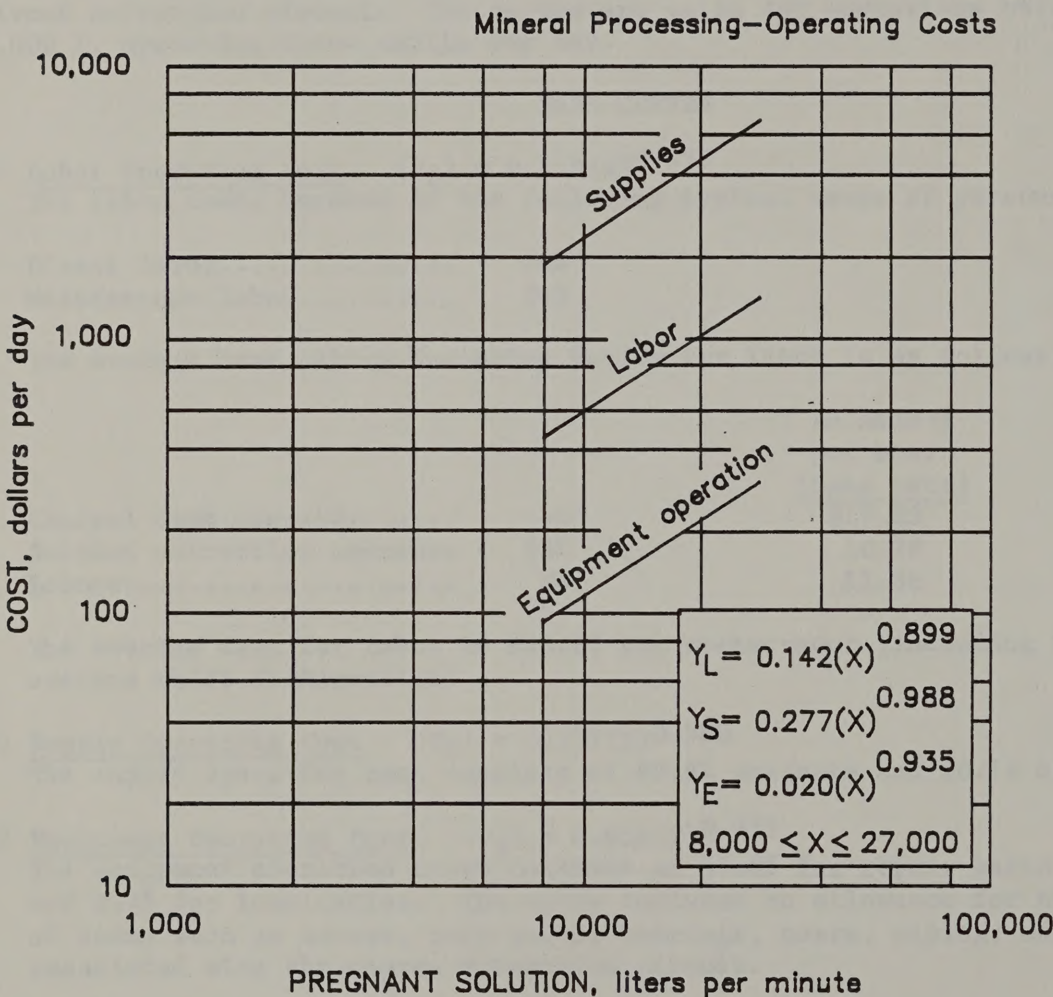
ADJUSTMENT FACTORS

Shift Factor The base curves are based on a three-shift-per-day operation. It is desirable to operate solvent extraction circuits on a continuous basis to minimize the formation of crud and/or emulsion. The crud and/or emulsion may contain radioactive materials which would require special disposal and/or processing at an additional cost. Therefore, no adjustment factor for a one- or two-shift operation is recommended for copper solvent extraction circuits.

<u>Number of Stages</u> The base case is premised on a total of eight stages four extraction and four stripping) in the solvent extraction. To adjust for a different number of stages, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.758(N)^{0.133}$

Equipment operation factor $(F_E) = 0.510(N)^{0.324}$
where N = total number of extraction and stripping stages.



7.1.5.2.2. Solvent extraction
COPPER

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.1. AMALGAMATION

The operating cost curves for amalgamation are given on a cost per day basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) at the feed rate (X), in metric tons of feed material to the amalgamation circuit per day. The curves are valid for operations between 0.40 and 65.0 mtpd. At low feed rates, the amalgamation circuit is normally operated on a one batch per day cycle, while at high feed rates, the operation is continuous.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 20.230(X)^{0.251}$
The operating labor costs consist of the following typical range of personnel:

	Small (0.4 to 1 mtpd)	Large (1 to 65 mtpd)
Direct labor................	100%	82%
Maintenance labor...........	0%	18%

The average base salary including burden for labor is as follows:

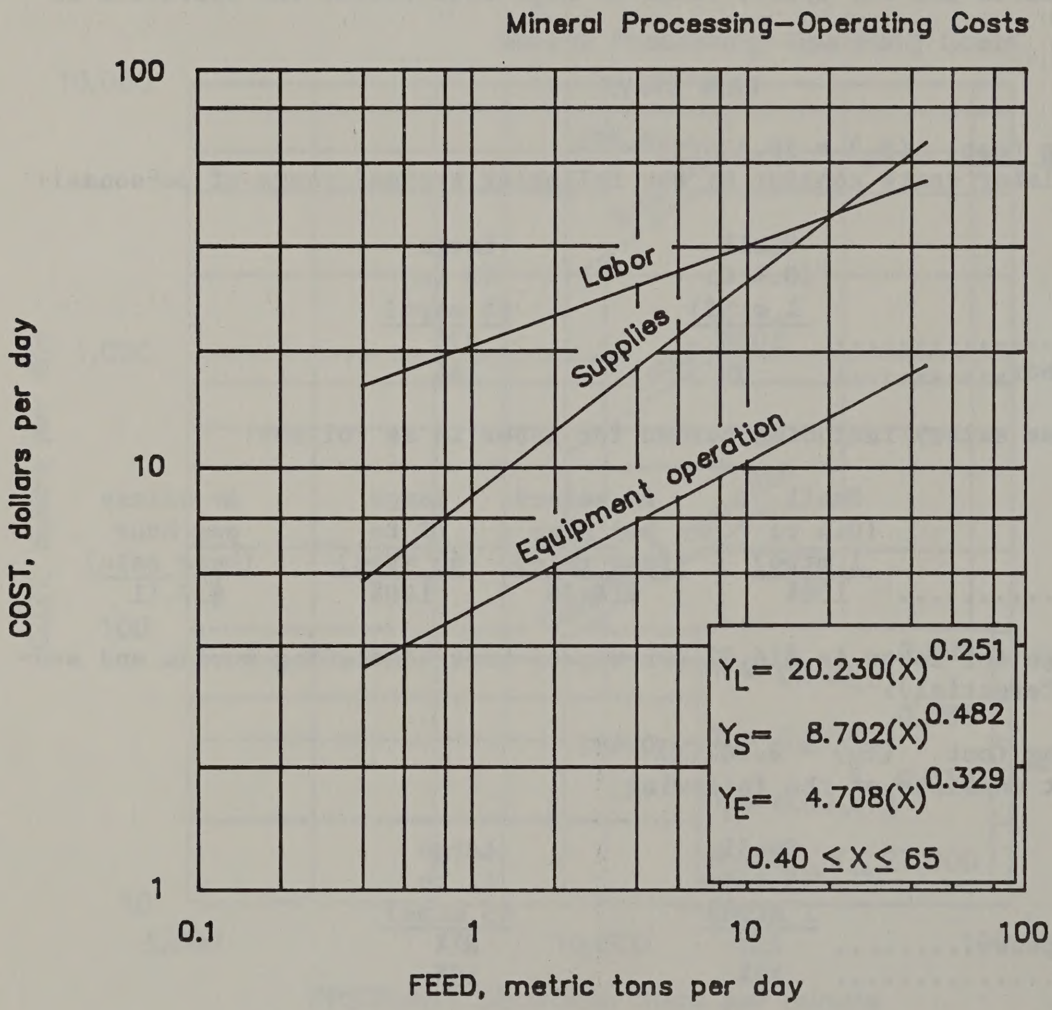
	Small (0.4 to 1 mtpd)	Av salary per hour (base rate)	Large (1 to 65 mtpd)	Av salary per hour (base rate)
Mill operator...........	100%	$16.78	100%	$17.11

The average wage for labor is $16.92 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 8.702(X)^{0.482}$
The supply cost consists of the following:

	Small (0.4 to 1 mtpd)	Large (1 to 65 mtpd)
Electric power.........	23%	81%
Mercury................	77%	19%

(E) Equipment Operating Cost $(Y_E) = 4.708(X)^{0.329}$
The equipment operation curve consists of 100% for repair parts and materials.



7.1.6.1. Amalgamation

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.2.1. BRINE RECOVERY
LITHIUM (WELLS)

The operating cost curves include the operation and maintenance of the brine recovery system, including solar evaporation ponds where applicable. The total daily operating cost for lithium from wells is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in liters of brine solution per minute pumped from the well field to the solar evaporation ponds. The curves are valid for operations between 1,300 and 9,700 L of brine solution, operating three shifts per day.

BASE CURVE

The operating cost curves for a lithium brine recovery includes the wells and solar evaporation ponds.

(L) Labor Operating Cost $(Y_L) = 5.985(X)^{0.635}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	80%
Maintenance labor...........	20%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Pond operator...............	38%	$16.78
Dragline operator...........	5%	16.78
Loader operator.............	9%	16.78
Truck driver................	15%	16.78
Laborer.....................	33%	11.68

The average wage for labor is $15.02 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.147(X)^{0.958}$
The supply operating cost consists of 99.5% electric power and 0.5% lime.

(E) Equipment Operating Cost $(Y_E) = 5.550(X)^{0.493}$
The equipment operating curve includes an allowance for the replacement of items such as motors, pump parts, piping, and the operation of mobile equipment associated with the lithium brine recovery system.

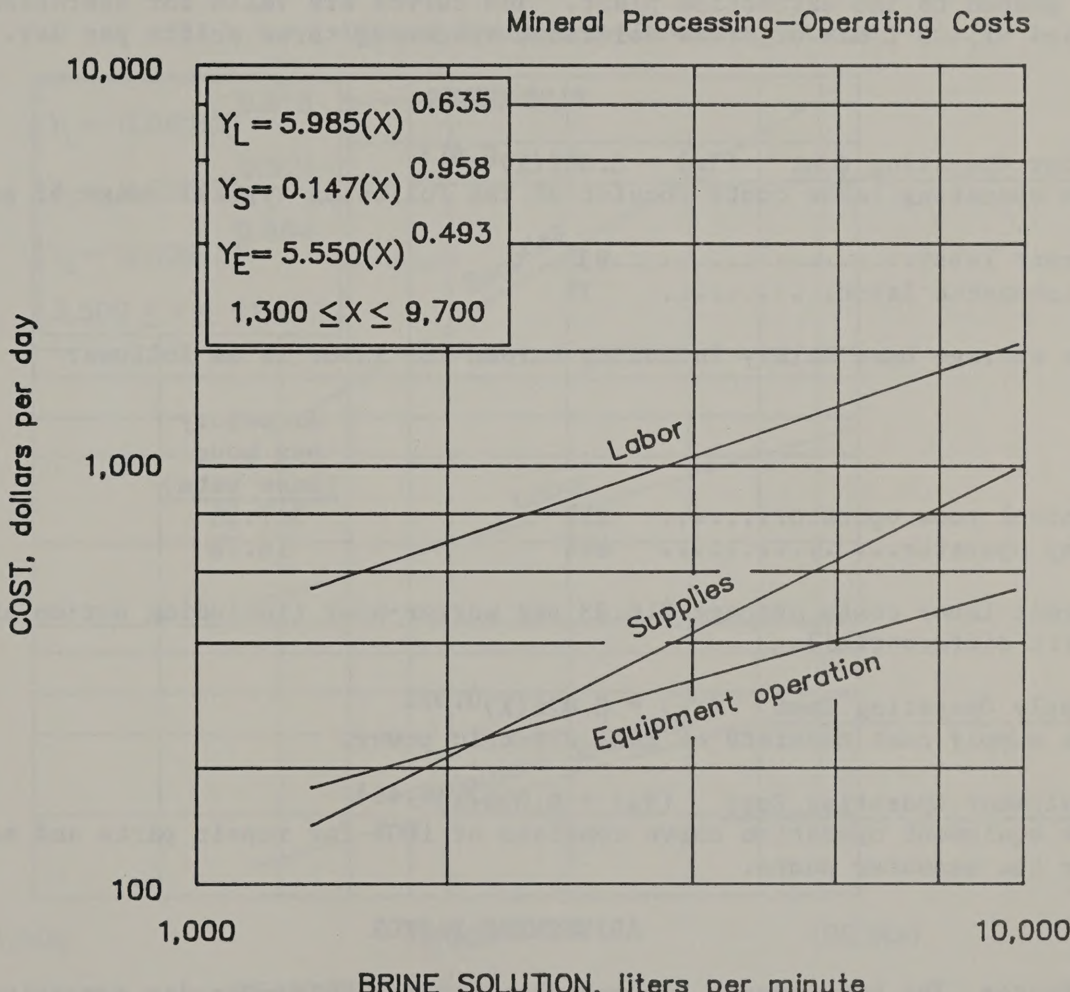
Diesel fuel.....................	34.0%
Gasoline........................	18.1%
Mobile equipment repair parts...	17.1%
Pumping system repair parts.....	12.5%
Tires...........................	11.3%
Lubrication.....................	7.0%

ADJUSTMENT FACTORS

<u>Well Depth Factor</u> The curves are based on an average well depth of 150 m. To adjust for a different well depth, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.078(D)^{0.508}$

Equipment operation factor $(F_E) = 0.921(D)^{0.016}$
where D = well depth, in meters.



7.1.6.2.1. Brine recovery
LITHIUM (WELLS)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.2.2. BRINE RECOVERY
MAGNESIUM (SEAWATER)

The operating cost curves for a brine recovery system from seawater for the extraction of magnesium consists of the seawater pumping system located on a pier. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in liters of seawater per minute pumped to the extraction plant. The curves are valid for operations between 3,500 and 91,400 L/min of brine solution, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.082(X)^{0.615}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	93%
Maintenance labor...........	7%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator.......	11%	$17.23
Pump operator...............	89%	16.78

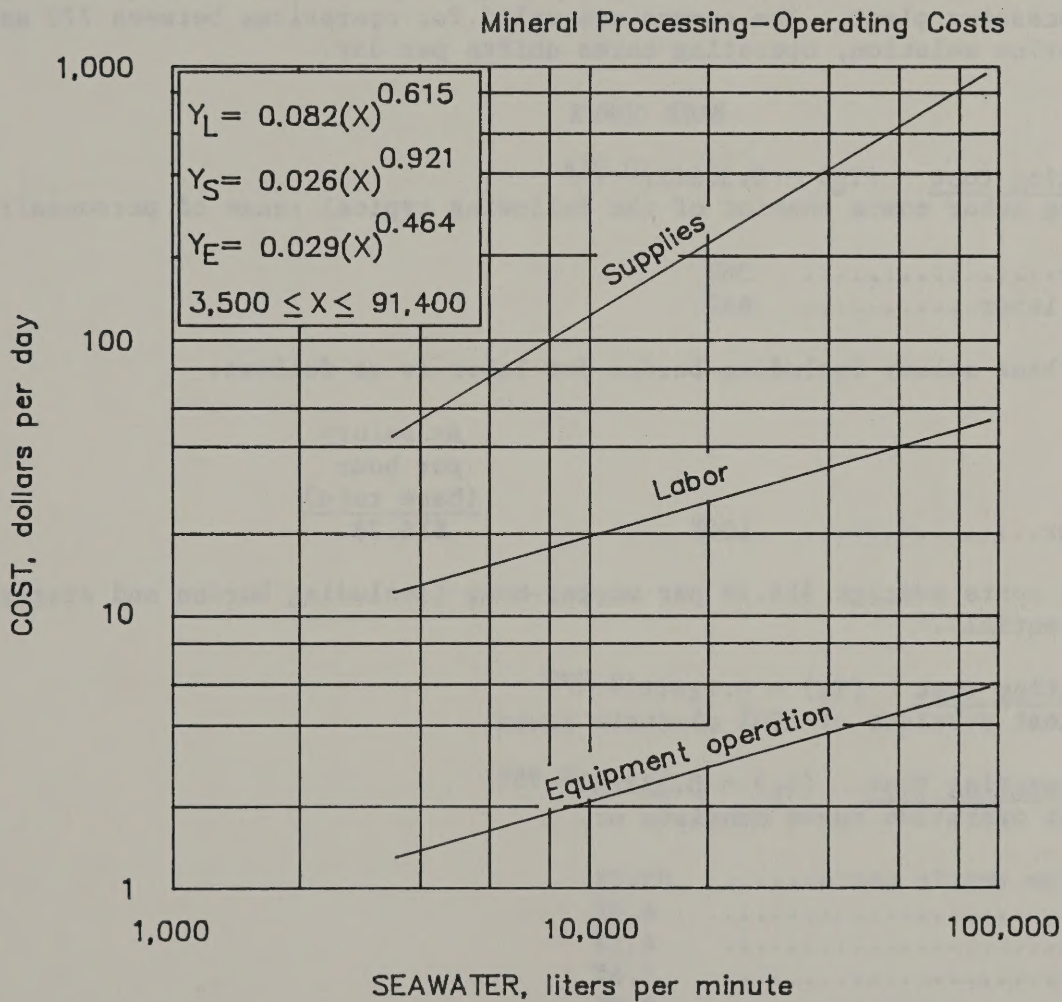
Direct labor costs average $16.83 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.026(X)^{0.921}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.029(X)^{0.464}$
The equipment operation curve consists of 100% for repair parts and materials for the seawater pumps.

ADJUSTMENT FACTOR

Shift Factor The base curves are based on a three-shift-per-day operation. It is desirable to operate the seawater pumping system on a continuous basis to maintain a steady feed to the subsequent processing circuits. No adjustment factor for a one- or two-shift-per-day operation is recommended.



7.1.6.2.2. Brine recovery
MAGNESIUM (SEAWATER)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.2.3. BRINE RECOVERY MAGNESIUM (WELLS)

The operating cost curves for a brine recovery system from wells for the extraction of magnesium consists of the well field pumping system and storage facility at the chemical plant. The total daily operating cost for magnesium from wells is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in liters of brine solution per minute pumped from the well field to the chemical processing plant. The curves are valid for operations between 770 and 7,000 L/min of brine solution, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.316(X)^{0.986}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	36%
Maintenance labor...........	64%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Pumpman-oiler...............	100%	$16.78

Direct labor costs average $16.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.729(X)^{0.979}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.223(X)^{0.969}$
The equipment operation curve consists of

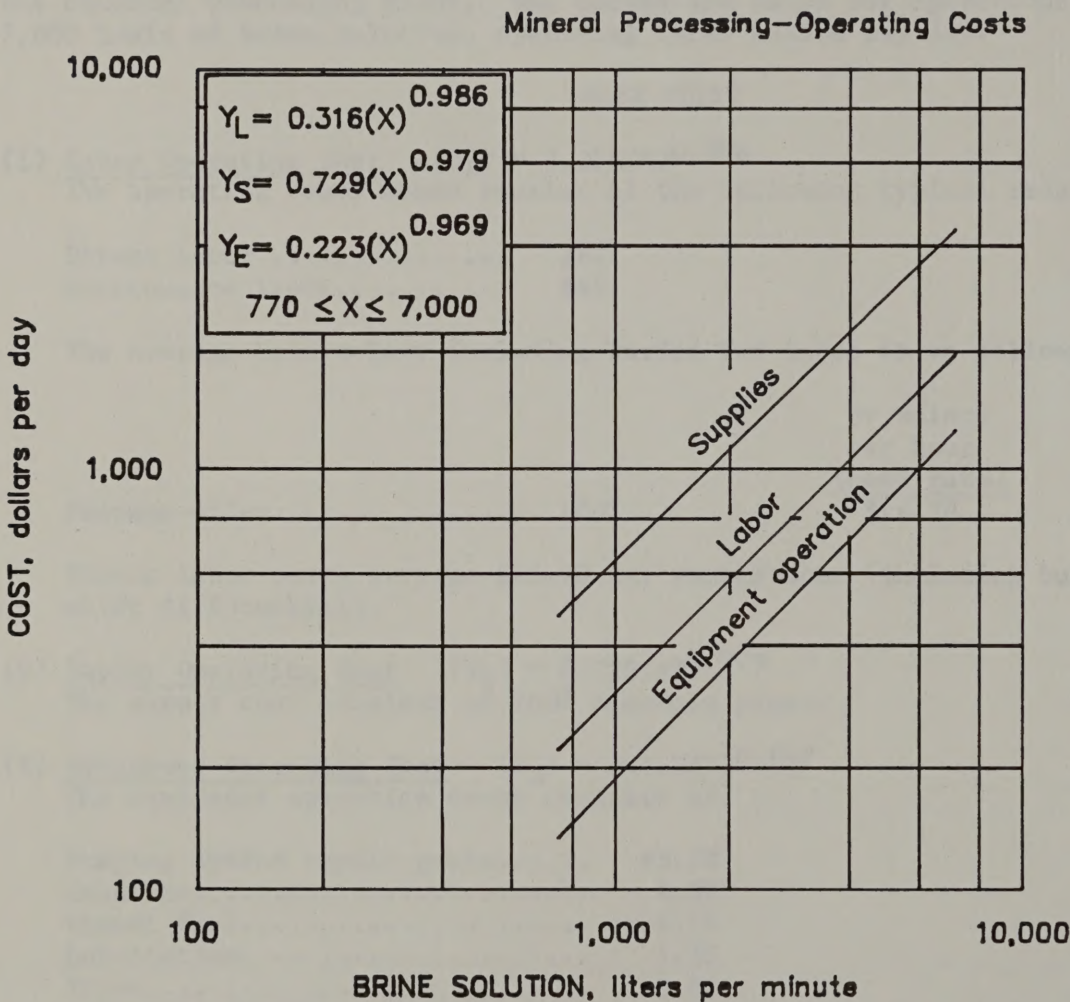
Pumping system repair parts......	85.7%
Gasoline.........................	6.9%
Diesel fuel......................	4.1%
Lubrication......................	1.6%
Tires............................	0.9%
Mobile equipment repair parts....	0.8%

ADJUSTMENT FACTOR

Well Depth Factor The curves are based on an average well depth of 1,400 m. To adjust for a different well depth, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.043(D)^{0.434}$

Equipment operation factor $(F_E) = 0.442(D)^{0.113}$
where D = well depth, in meters.



7.1.6.2.3. Brine recovery
MAGNESIUM (WELLS)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.2.4. BRINE RECOVERY MAGNESIUM-POTASH (LAKES)

The operating cost curves for a brine recovery system from lakes for the extraction of magnesium and potash consist of a brine pumping system, solar evaporation ponds, mobile and harvesting equipment. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in billion liters of brine solution per year pumped from the lake to the to the solar evaporation ponds. The curves are valid for operations between 50 and 105 billion L/yr of brine solution, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 49.455(X)^{0.886}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	83%
Maintenance labor...........	17%

The average base salary including burden for labor is as follows:

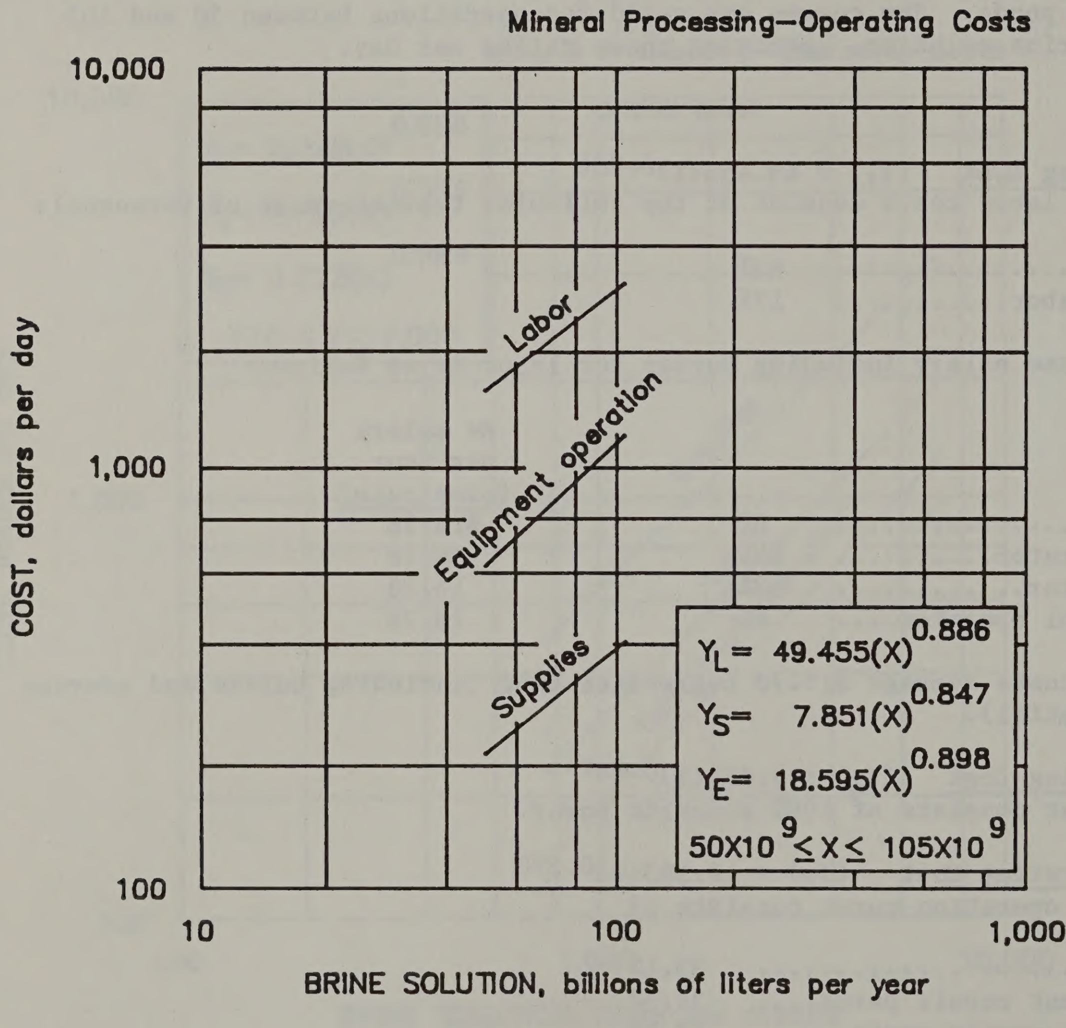
		Av salary per hour (base rate)
Pumpman.....................	6%	$16.78
Equipment operator..........	63%	16.78
Scraper operator............	23%	16.78
Harvest control operator....	8%	16.78

Direct labor costs average $16.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 7.851(X)^{0.847}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 18.595(X)^{0.898}$
The equipment operation curve consists of

Diesel fuel......................	35.1%
Mobile equipment repair parts....	34.5%
Pumping system repair parts......	12.2%
Tires............................	7.8%
Gasoline.........................	7.1%
Lubrication......................	3.3%



7.1.6.2.4. Brine recovery
MAGNESIUM/POTASH (LAKES)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.2.5. BRINE RECOVERY
POTASH (FLOODED MINE)

The operating cost curves for a brine recovery system from a flooded mine for the extraction of potash consists of the brine pumping system, solar evaporation ponds, and mobile and harvesting equipment. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in liters of brine solution per minute pumped from the flooded mine to the solar evaporation ponds. The curves are valid for operations between 3,200 and 13,000 L/min, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 4.349(X)^{0.638}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	84%
Maintenance labor...........	16%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Pond operator...............	37%	$16.78
Scraper operator............	26%	16.78
Laborer.....................	37%	11.68

Direct labor costs average $15.20 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.134(X)^{0.948}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $Y_E = 0.569(X)^{0.711}$
The equipment operation curve consists of

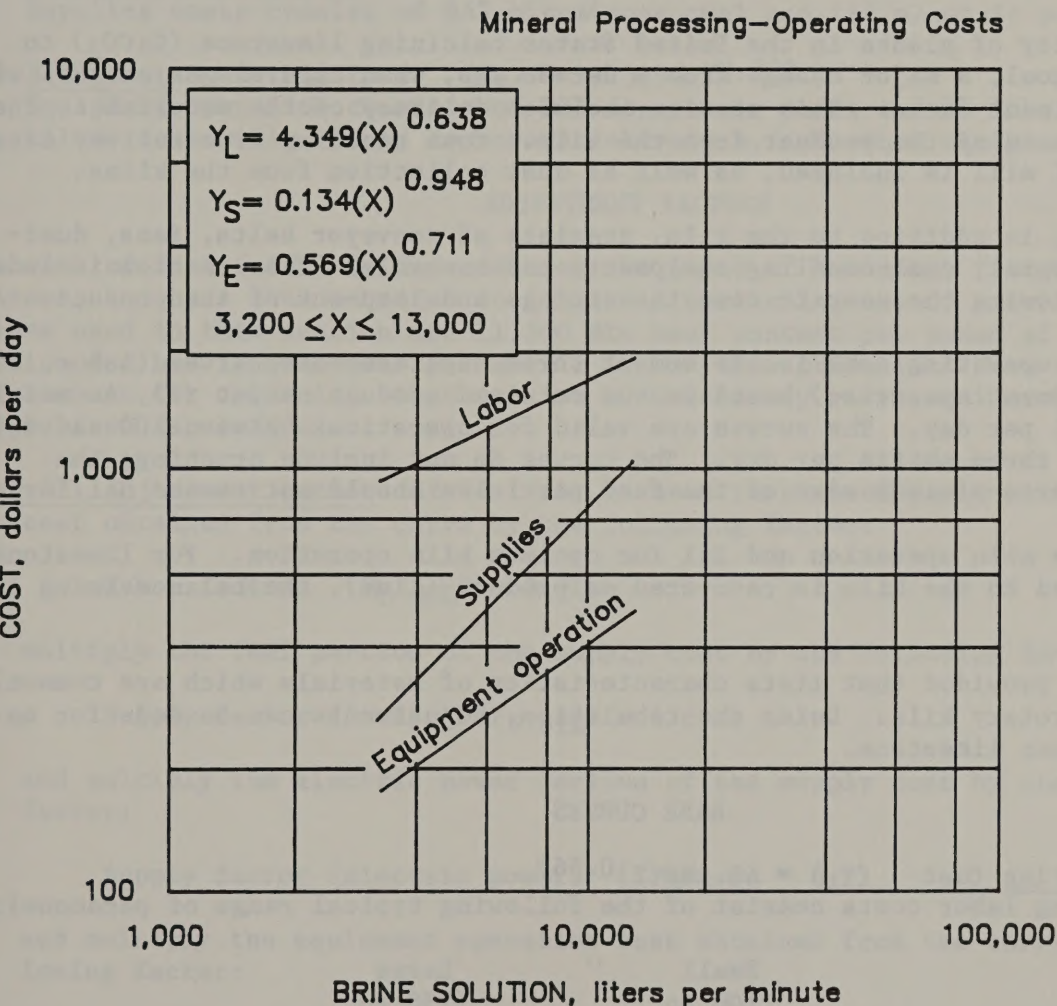
Gasoline........................	28.8%
Diesel fuel.....................	21.8%
Mobile equipment repair parts....	17.3%
Tires...........................	16.8%
Pumping system repair parts......	10.6%
Lubrication.....................	4.7%

ADJUSTMENT FACTOR

Pumping Head Factor The curves are based on an average pumping head of 244 m. To adjust for a different pumping head, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.106(H)^{0.408}$

Equipment operation factor $(F_E) = 0.832(H)^{0.034}$
where H = pumping head, in meters.



7.1.6.2.5. Brine recovery
POTASH (FLOODED MINE)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.3. CALCINATION (ROTARY KILN)

This section covers the cost of calcining (or applying high heat to) limestone or other ores or materials, using appropriate adjustment factors. Common to all these applications is the use of a refractory-lined rotary kiln, with the heat flowing counter current to the flow of the product. No utilization of waste heat is considered although the rotary-kiln treatment of certain materials is accompanied by waste-heat boilers or other energy-conserving equipment.

The great majority of plants in the United States calcining limestone ($CaCO_3$) to lime (CaO) use coal, a major change from a decade ago, when natural gas or fuel oil were the predominant fuels. This section includes delivery of the material to the kiln and conveyance of the product from the kiln. Coal handling from railway cars through the coal mill is included, as well as dust collection from the kilns.

Major equipment, in addition to the kiln, consists of conveyor belts, fans, dust-collecting equipment, coal-handling equipment, and controls. This section includes a subsection allowing the user to cost the storage and load-out of the product.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the calcined product output (X), in metric tons of material per day. The curves are valid for operations between 100 and 6,000 mtpd, operating three shifts per day. The curves do not include crushing; the ratio of maximum-to-minimum size of the feed particles should not exceed 3:1 for mini-
mally acceptable kiln operation and 2:1 for optimum kiln operation. For limestone, about 62% of feed to the kiln is recovered as product (lime), the balance being lost as dust or CO_2.

A tabulation is provided that lists characteristics of materials which are commonly processed in a rotary kiln. Using the tabulation, adjustments can be made for materials other than limestone.

BASE CURVES

(L) <u>Labor Operating Cost</u> $(Y_L) = 48.580(X)^{0.567}$

The operating labor costs consist of the following typical range of personnel:

	Small (100 to 750 mtpd)	Large (750 to 6,000 mtpd)
Direct labor...............	46%	19%
Maintenance labor...........	54%	81%

The average base salary including burden for labor is as follows:

	Small (100 to 750 mtpd)	Large (750 to 6,000 mtpd)	Av salary per hour (base rate)
Kiln operator..............	74%	62%	$15.89
Utility....................	17%	19%	14.56
Coal handling	9%	19%	14.56

The average wage for labor is $15.66 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 16.038(X)^{0.991}$
Supplies costs consist of 84% bituminous coal and 16% electric power.

(E) Equipment Operating Cost $(Y_E) = 12.318(X)^{0.722}$
Equipment operation consists of 93% for repair parts and 7% lubricants for kilns, coal mills, fans, conveyors, elevators, and other equipment.

ADJUSTMENT FACTORS

The cost of fuel (coal) is dependent on the price of the coal, freight rates, heat content, and heat rate required to calcine a particular ore or material. Heating values used in this section are 11,300 Btu heat content per pound of coal and 7.44 million Btu heat requirement per metric ton of lime produced. Note that the heat requirement for calcining other ores or materials may vary considerably from this figure (see tabulation).

Fuel Oil Adjustment Factor If fuel oil is used instead of coal, multiply the labor cost obtained from the curve by the following factor:

Labor factor $(F_{L\ OIL}) = 0.92$

multiply the fuel portion of the supply cost by the following factor:

Supply factor (fuel) $(F_{S\ OIL}) = 4.6$

and multiply the electric power portion of the supply cost by the following factor:

Supply factor (electric power) $(F_{S\ OIL}) = 0.71$

and multiply the equipment operation cost obtained from the curve by the following factor:

Equipment operation factor $(F_{E\ OIL}) = 0.97$

Natural Gas Adjustment Factor If natural gas is used instead of coal multiply the labor cost obtained from the curve by the following factor:

Labor factor $(F_{L\ GAS}) = 0.85$

multiply the fuel portion of the supply cost by the following factor:

Supply factor (fuel) $(F_{S\ GAS}) = 2.2$

and multiply the electric power portion of the supply cost by the following factor:

Supply factor (electric power) $(F_{S\ GAS}) = 0.7$

and multiply the equipment operation cost obtained from the curve by the following factor:

Equipment operation factor $(F_{E\ GAS}) = 0.95$

Heat Rate Factor When the heat rate for calcining a material is different than that for limestone (7.44 MMBtu/mt), multiply the fuel portion of the supply curve by the appropriate value from the fuel rate column of product, of the tabulation that follows.

Length-to-Diameter Ratio Factor For length-to-diameter (L/D) ratios different than 32, multiply the electric power portion of the supply curve by the following factor (see the length-diameter ratio), column of the following tabulation for ratios for various commodities):

Supply factor (electric power) $(F_{S\ L/D}) = 0.710(R)^{0.098}$
where R = length-to-diameter multiplier from the table.

Specific Gravity Factor For specific gravities different than 1.18, multiply the electric power portion of the supply curve by the following factor (see the specific gravity column of the tabulation for SG values for various commodities).

Supply factor (electric power) $(F_{S\ SG}) = 0.990(S)^{0.059}$
where S = specific gravity multiplier from the table.

Actual costs, unit prices, wages, and other values, if known, may be substituted for values given in the above descriptions.

STORAGE AND LOADOUT OF PRODUCT

Should it be desired to store the product from the kiln and load it into either trucks or railroad cars, this section will supply costs for this operation. Included are conveyors, bucket elevators, vibrating-screen, crusher, and steel storage bins. The total daily operating cost is the sum of three separate cost equations (labor, supplies, and equipment operation) based on the product storage, load-out rate (X), in metric tons material per day. The curves are valid for operations between 100 and 6,000 mtpd, operating three shifts per day.

(L) Labor Operating Cost $(Y_L) = 29.610(X)^{0.470}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	32%
Maintenance labor...........	68%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Conveyor operator...........	100%	$14.56

The average wage for labor is $14.81 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.450(X)^{0.685}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 37.450(X)^{0.400}$
The equipment operation curve consist of 93% for repair parts and 7% for lubricants for conveyors, elevators, screens, and the crusher.

Rotary kiln calcination - Feed and product characteristics and cost factors

Product and feed or reaction	Normal moisture in feed, %	Fuel rate[1] Btu/mt product	Fuel cost multi-plier[2]	Length diameter ratio[3] (L/D)	Specific gravity[4]
Lime (CaO): Limestone	0- 3	7.44	1.00	32	1.18
Lime, magnesia: Dolomite	0- 3	7.55	1.01	35	1.18
Alumina: Aluminum hydroxide	15	5.40	0.73	30	1.04
Light weight aggregate: Clay, shale	3- 7	2.54	0.34	18	0.56
Petroleum coke: Burn off volatiles	6-14	1.65	0.22	20	0.69
Clay: Evaporate H_2O and densifier	0-24	5.62	0.76	24	0.85
Periclase: Brucite, magnesiz	50	12.68	1.70	30	1.93
Phosphate:					
Nodulize	15-30	3.31	0.44	22	1.28
Calcine $CaCO_3$	0- 1	4.32	0.58	36	1.28
Burn off carbonaceous material	10-15	2.04	0.27	20	1.28
Diatomaceous earth: Burn off carbonaceous material	0- 5	4.8	0.63	15	0.52
Manganese oxide: Manganese carbonate	3-10	4.5	0.60	28	1.90

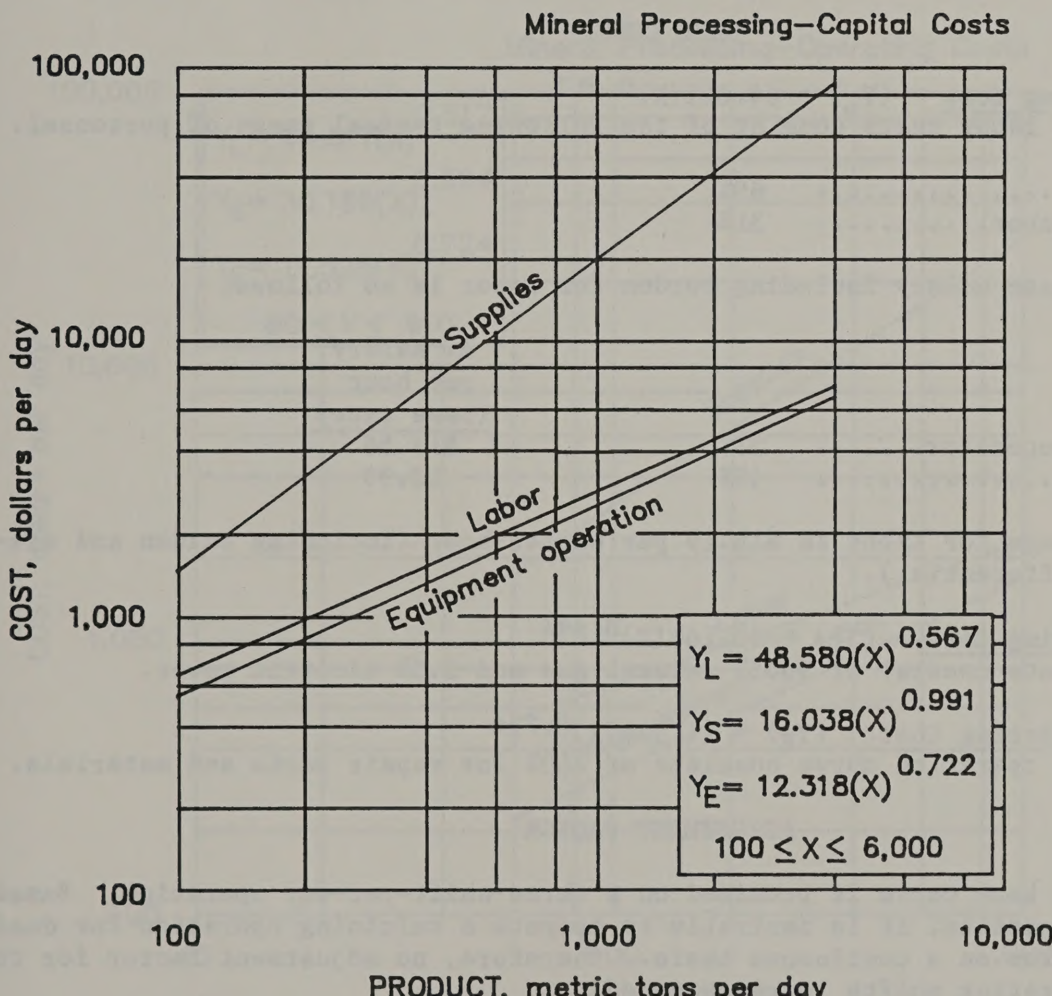
[1]Lime value is from kiln manufacturer; others are averages from Engineering and Mining Journal, June 1980, page 139.

[2]To determine cost of coal burned to calcine a particular material, multiply the fuel portion of the supplies curve by the appropriate multiplier.

[3]Averages for kiln: from Engineering and Mining Journal, June 1980, page 139.

[4]Approximate average values (bulk form, i.e., including voids) of materials during processing in the kiln; values from various sources: KVS Handbook, Perry's Engineering Manual, CRC Handbook.

NOTE.—No sulfides are considered because: 1) sulfides are not usually roasted in a rotary kiln (multiple-hearth vertical furnaces are frequently used), 2) the varying amounts of sulfur (oxidation of which is exothermic) would make fuel adjustment factors cumbersome, and 3) a flue gas scrubber (with lime addition) is probably necessary to meet environmental requirements (unless the SO_2 is used for acid manufacturing, which is not infrequently the case).



7.1.6.3. Calcination (rotary kiln)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.4. CALCINING (DEADBURNED MAGNESIUM)

The operating cost curves for calcining are given on a metric tons of feed per day basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) at the capacity rate (X), in metric tons of feed material to the kiln per day, The curves are valid for capacities between 60 and 910 mtpd, operating on a continuous basis.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 64.611(X)^{0.517}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	69%
Maintenance labor...........	31%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator.......	51%	$17.56
Kiln helper.................	49%	13.99

The average wage for labor is $16.19 per worker-hour (including burden and average shift differential).

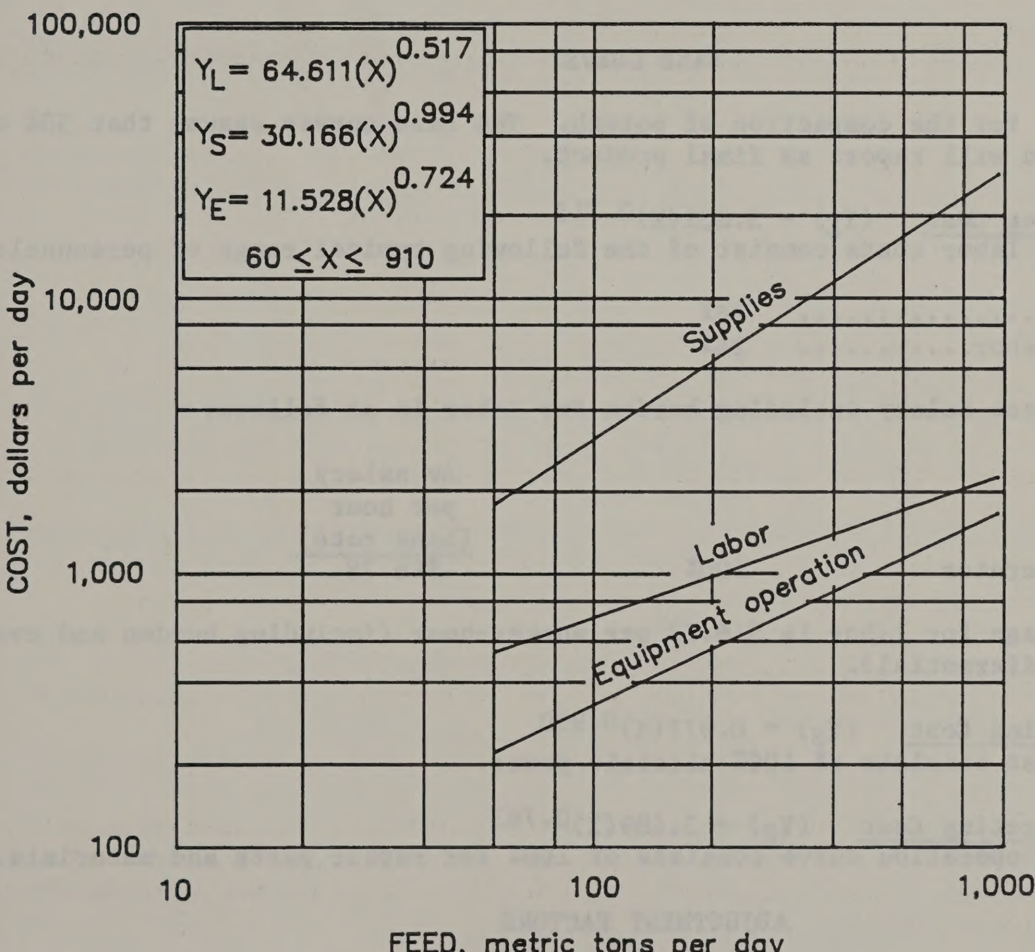
(S) Supply Operating Cost $(Y_S) = 30.166(X)^{0.994}$
The supply costs consist of 96.5% natural gas and 3.5% electric power.

(E) Equipment Operating Cost $(Y_E) = 11.528(X)^{0.724}$
The equipment operation curve consists of 100% for repair parts and materials.

ADJUSTMENT FACTOR

Shift Factor The base curve is premised on a three-shift-per-day operation. Based on industry practice, it is desirable to operate a calcining operation for deadburned magnesium on a continuous basis. Therefore, no adjustment factor for the number of operating shifts is recommended.

Mineral Processing—Operating Costs



7.1.6.4. Calcining (deadburn magnesium)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.5. COMPACTION

The operating costs for compaction are given on a metric ton per day of final product basis for the compaction of potash. The costs include the operation of compactors, impactors, screens, screw conveyors, belt conveyors, and bucket elevators. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the compaction rate (X), in metric tons of final compacted product per day. The curves are valid for operations between 220 and 3,150 mtpd, operating three shifts per day.

BASE CURVE

The base curve is for the compaction of potash. The base curves assume that 50% of the compactor feed will report as final product.

(L) Labor Operating Cost $(Y_L) = 3.831(X)^{0.715}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	76%
Maintenance labor...........	24%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Compaction operator	100%	$16.78

The average wage for labor is $16.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.977(X)^{0.990}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 3.489(X)^{0.783}$
The equipment operation curve consists of 100% for repair parts and materials.

ADJUSTMENT FACTORS

Compactor Feed Product Factor The dominant factor in compaction is the percent of compactor feed reports as final product. The base curve that is predicated on 50% of the compactor feed reporting as final product. The normal range of this variable is 25% to 75% of the feed reporting as product. To adjust for varying quantities of product in the compactor feed, multiply the costs obtained from the curves by the following factors:

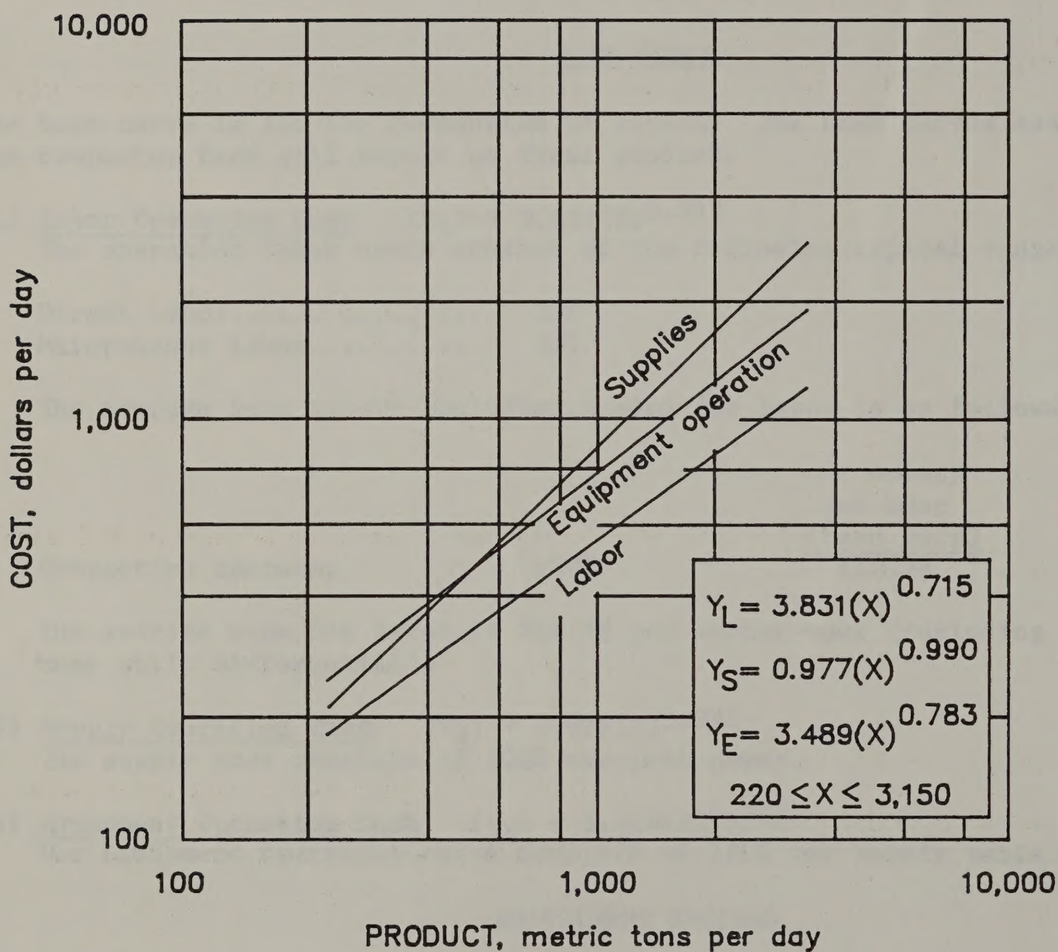
Labor factor $(Y_L) = 1.020[(50/P)]^{0.721}$

Supply factor $(Y_S) = 50/P$

Equipment operating factor $(Y_E) = 0.992[(50/P)]^{0.798}$
where P = percent of feed reporting as product.

Shift Factor The curve is based on a three-shift-per-day operation. Typically, compaction circuits must be run continuously. For a one- or two-shift operation, decrease the operating costs proportionately.

Mineral Processing—Operating Costs



7.1.6.5. Compaction

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.6. CRYSTALLIZATION

The operating cost curves for a potash crystallization circuit include its operation and maintenance of the crystallization circuit. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the production rate (X), in metric tons of crystallized product per day. The curves are valid for operations between 50 and 4,350 mtpd, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 21.076(X)^{0.549}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	52%
Maintenance labor...........	48%

The average base wages including burden for labor are as follows:

		Av salary per hour (base rate)
Control room operator.......	33%	$17.56
Crystallizer operator.......	60%	16.78
Laborer.....................	7%	13.86

The average wage for labor is $16.95 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 5.317(X)^{0.990}$
The supply cost consists of 80.1% natural gas, 19.3% electric power, and 0.6% flocculant.

(E) Equipment Operation Cost $(Y_E) = 4.492(X)^{0.678}$
The equipment operation curve consists of 100% for repair parts and materials. The curve includes an allowance for the replacement of items such as motors, pumps parts, bearings, piping, and parts associated with the crystallization circuit.

ADJUSTMENT FACTORS

Shift Factor The base curves are based on a three-shift-per-day operation. It is desirable to operate a crystallization circuit on a continuous basis. Therefore, no adjustment factor for the number of shifts is recommended for crystallization.

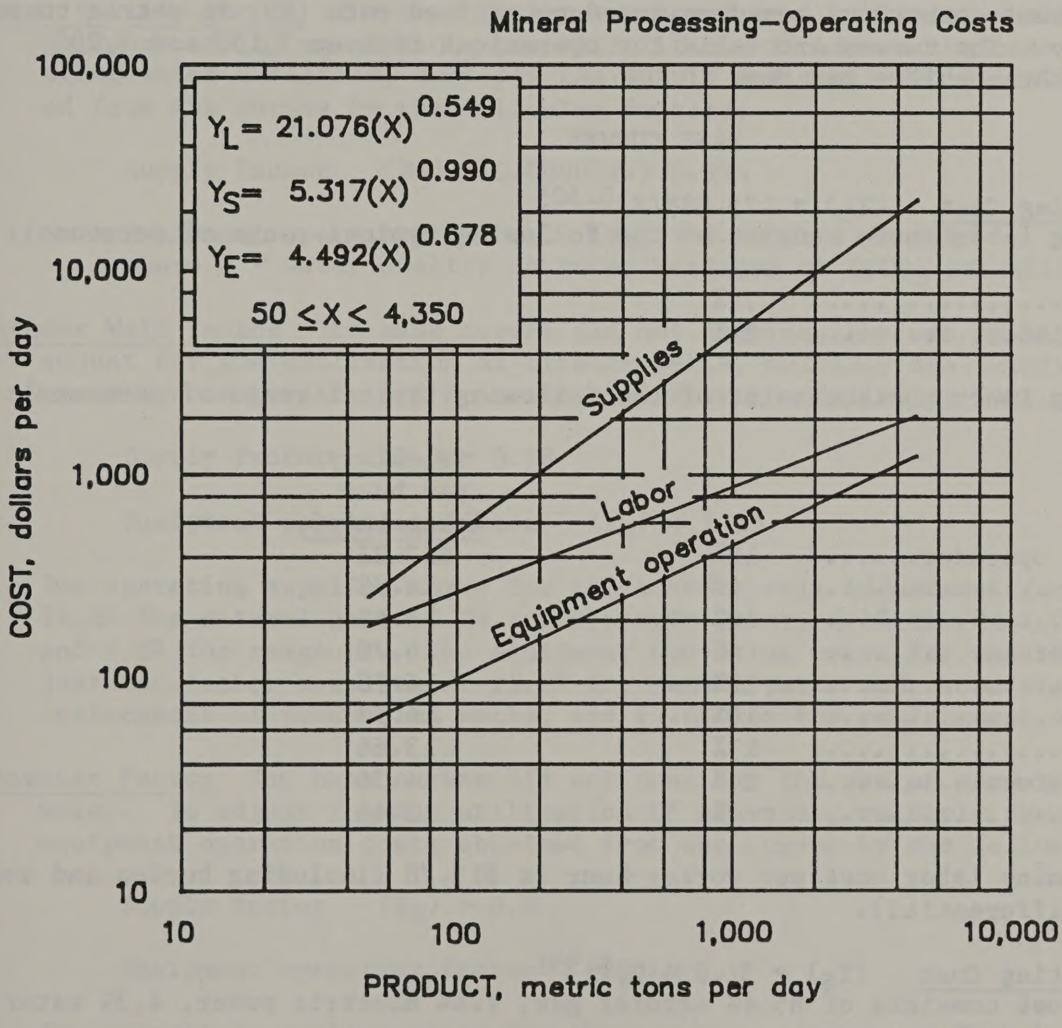
Leaching Factor The base curves are premised on feed sources from effluents, baghouses, and dust collectors to the crystallization circuit for the recovery of crystallized potash. To adjust for the leaching of tailings or ore (no dis-

solving tanks), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.24$

Supply factor $(F_S) = 2.02$

Equipment operation factor $(F_E) = 1.25$



7.1.6.6. Crystallization

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.7. FRASCH PROCESS

The operating cost curves for Frasch process include the production of molten sulfur from underground deposits through the loading facility for transpor- tation in rail-cars or trucks to the consumer. Major equipment items operated include the sulfur wells, hot water process softeners, air compressors, mine water heaters, reagent handling system, sulfur relay stations, sulfur loading facilities, and pumps. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on an adjusted feed rate (X), in metric tons of sulfur per day. The curves are valid for operations between 1,150 and 7,900 mtpd, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 175.888(X)^{0.585}$

The operating labor costs consist of the following typical range of personnel:

Direct labor................	71%
Maintenance labor...........	29%

The operating labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Control room operator.......	11%	$17.23
Operator A..................	4%	16.78
Operator B..................	10%	13.66
Equipment operator..........	6%	16.78
Truck driver................	11%	16.78
Driller.....................	10%	16.78
Driller B...................	17%	13.66
Utility operator............	24%	14.56
Technician..................	7%	15.44

The average mine labor cost per worker-hour is $15.78 (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 31.934(X)^{0.991}$

The supply cost consists of 85.4% natural gas, 7.4% electric power, 4.3% water, 2.4% fuel, and 0.5% reagents.

(E) Equipment Operating Cost $(Y_E) = 4.918(X)^{0.997}$

The equipment operation curve consists of 80.8% for the replacement of production wells and 19.2% for repair parts and materials.

ADJUSTMENT FACTORS

<u>Water-Sulfur Ratio Factor</u> The base curve is based on a water-sulfur ratio of 3,000 gal of water per metric ton of sulfur produced. To adjust the base curve for other ratios, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.0003(R)+0.030$

Equipment operating factor $(F_E) = 0.00002(R)+0.932$
where R = water/sulfur ratio, in gallons of water per metric ton of sulfur produced.

<u>Water Quality Factor</u> The base curves are based on a raw water quality as total hardness of 100 mg of $CaCO_3$ per milliliter. To adjust the base curves for other water qualities, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.00007(W)+0.994$

Equipment operating factor $(F_E) = 0.00001(W)+0.999$
where W = water quality as total hardness of $CaCO_3$ per milliliter.

<u>Bleeder Well Factor</u> The base curves did not consider the use of bleeder wells. To adjust for the utilization of bleeder wells, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.58$

Equipment operating factor $(F_E) = 1.35$

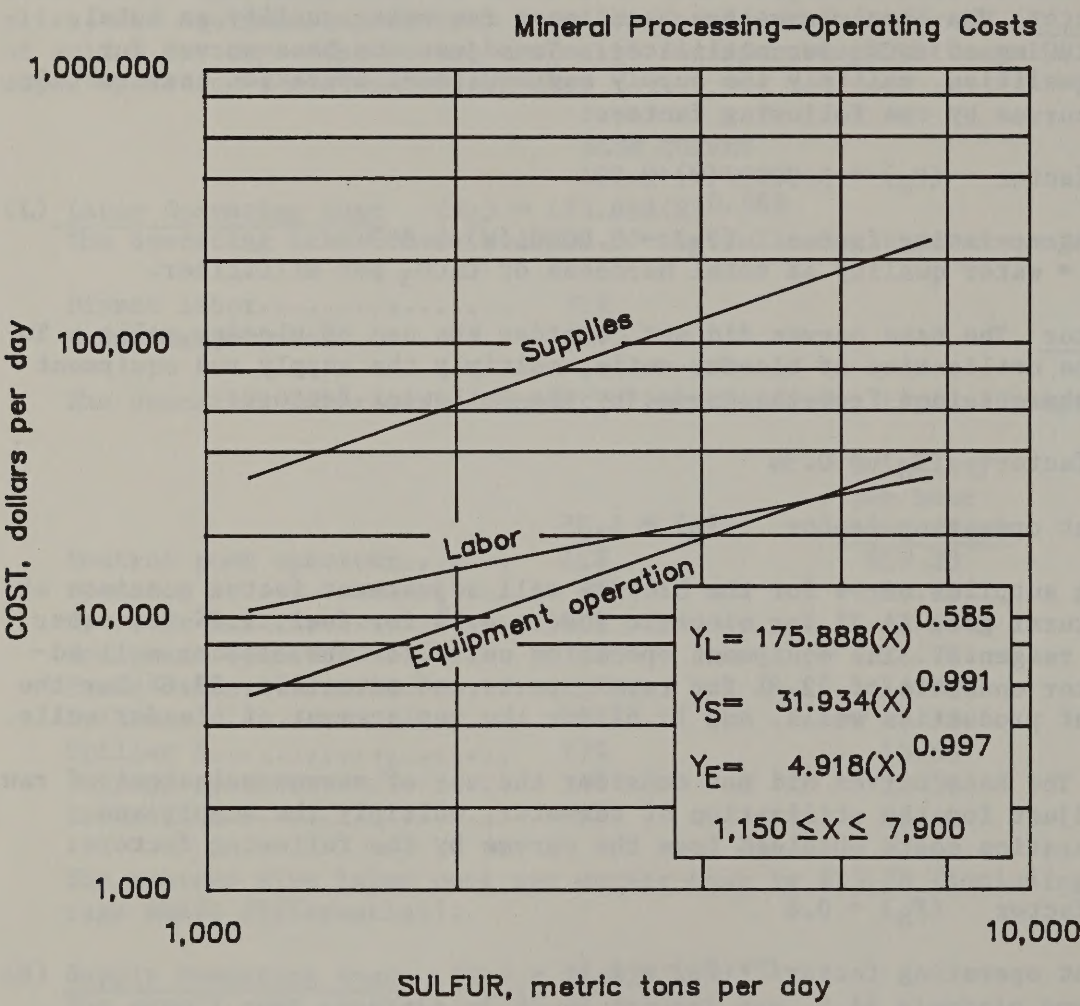
The operating supplies curve for the bleeder well adjustment factor consists of 71.3% for natural gas, 14.2% for electric power, 4.1% for fuel, 2.2% for water, and 8.2% for reagents. The equipment operation curve for the bleeder well adjustment factor consists of 22.8% for repair parts and materials, 59.6% for the replacement of production wells, and 17.6% for the replacement of bleeder wells.

<u>Seawater Factor</u> The base curves did not consider the use of seawater instead of raw water. To adjust for the utilization of seawater, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.8$

Equipment operating factor $(F_E) = 1.1$

The operating supplies curve for the seawater adjustment factor consists of 80.8% or natural gas, 9.3% for electric power, 2.9% for fuel, and 7.0% for reagents. The equipment operation curve for the seawater adjustment factor consists of 26.4% for repair parts and materials and 73.6% for replacement of production wells.



7.1.6.7. Frash process

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.8. HANDSORTING

This section provides costs for the removal from run-of-mine ore of selected grades of material by hand. The substances removed may be valueless gangue, waste rock not worth processing, or unusually rich ore. Any costs associated with moving the material to the sorting surface are not included in this section. Ore may be coming from another process section or from the mining operation. It is assumed that the ore will be delivered on a belt conveyor; if a different method is used, costs should be adjusted. Costs in this section include moving the material past the pickers and sorting the material into bins or piles by hand. Costs obtained from this section should not be applied to gemstones.

The total daily operating cost is the sum of three separate cost curves (labor, supply, and equipment operation) based on the feed rate to the picking belt (X), in metric tons of material per day. The curves are valid for operations between 40 and 2,000 mtpd, operating one shift per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 9.249(X)^{0.983}$

Using local labor rates and a range of 0.049 to 4.5 mt of selected material picked per hour, a daily labor rate can be determined. The labor curve is based on an average of 1 mt of selected material picked per hour, selected material equalling 10% of total feed.

The operating labor costs consist of the following typical range of personnel:

Direct labor................	99%
Maintenance labor...........	1%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Hand pickers................	100%	$13.66

The average wage for labor is $13.66 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.002(X)^{1.268}$

The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.093(X)^{0.916}$

Equipment operating costs are dependent on the type of sorting surface used. Surfaces used could include sorting floors, tables, fixed chutes and grizzlies, belt conveyors, pan conveyors, revolving tables or shaking surfaces. Equipment operating costs would range from insignificant for a sorting floor to $77.97 per day for a 42-in by 110-ft (106.7-cm by 33.5-m) belt conveyor operating 8 h/d.

The equipment operation curve covers the daily operation cost for belt conveyors and consists of 94% for repair parts and 6% for lubricants.

Costs for water needed to wash the material before sorting is included in the water supply section.

ADJUSTMENT FACTOR

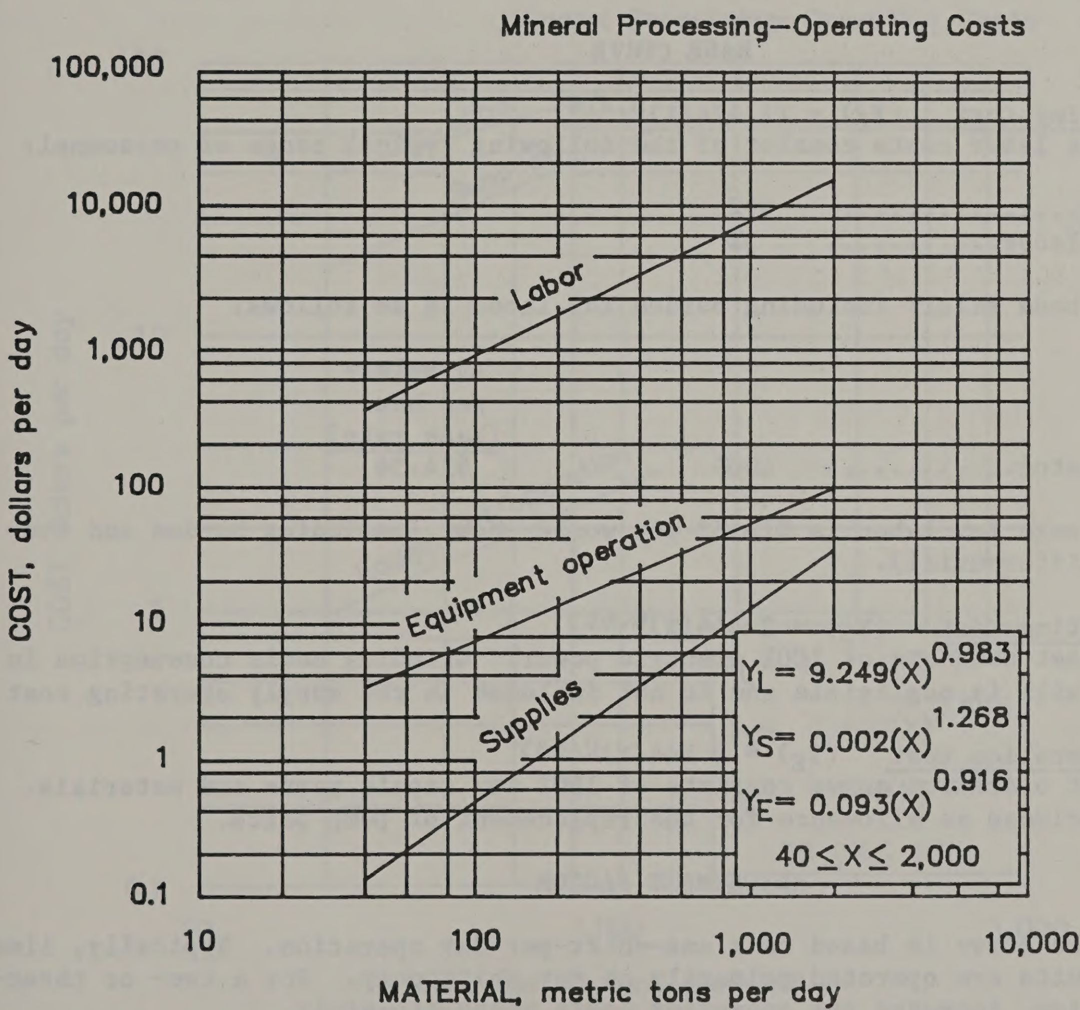
Labor Factor To calculate the labor cost for different conditions, use the following formula:

Labor cost per day = [(W)(X)(G)]/R
where W = local labor rate, in dollars per hour,
X = total feed to the picking belt, in metric tons per day,
G = percent picked, expressed as a decimal,
and R = amount of selected material picked per laborer, in metric tons per hour.

The following Table gives three typical rates of handsorting for gold-silver operations:

Typical handsorting rates for gold-silver operations

Metric tons picked per laborer hour (R)	Total feed picked (G)
1.4	15%
0.15-0.23	10%
0.68	1.75%-2.25%



7.1.6.8. Handsorting

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.9. LIME SLAKING

The operating cost curves for lime slaking are given on a per shift basis rather than a cost per day basis. The costs include the operation of the lime loop pumps. The total daily operating cost is the sum of three separate cost curves (labor, supply, and equipment operation) based on the feed rate (X), in metric tons of lime per shift. The curves are valid for operations between 20 and 125 mt/sh, operating one shift per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 11.474(X)^{0.416}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	97%
Maintenance labor..........	3%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Mill suboperator...........	100%	$14.56

The average wage for labor is $14.63 per worker-hour (including burden and average shift differential).

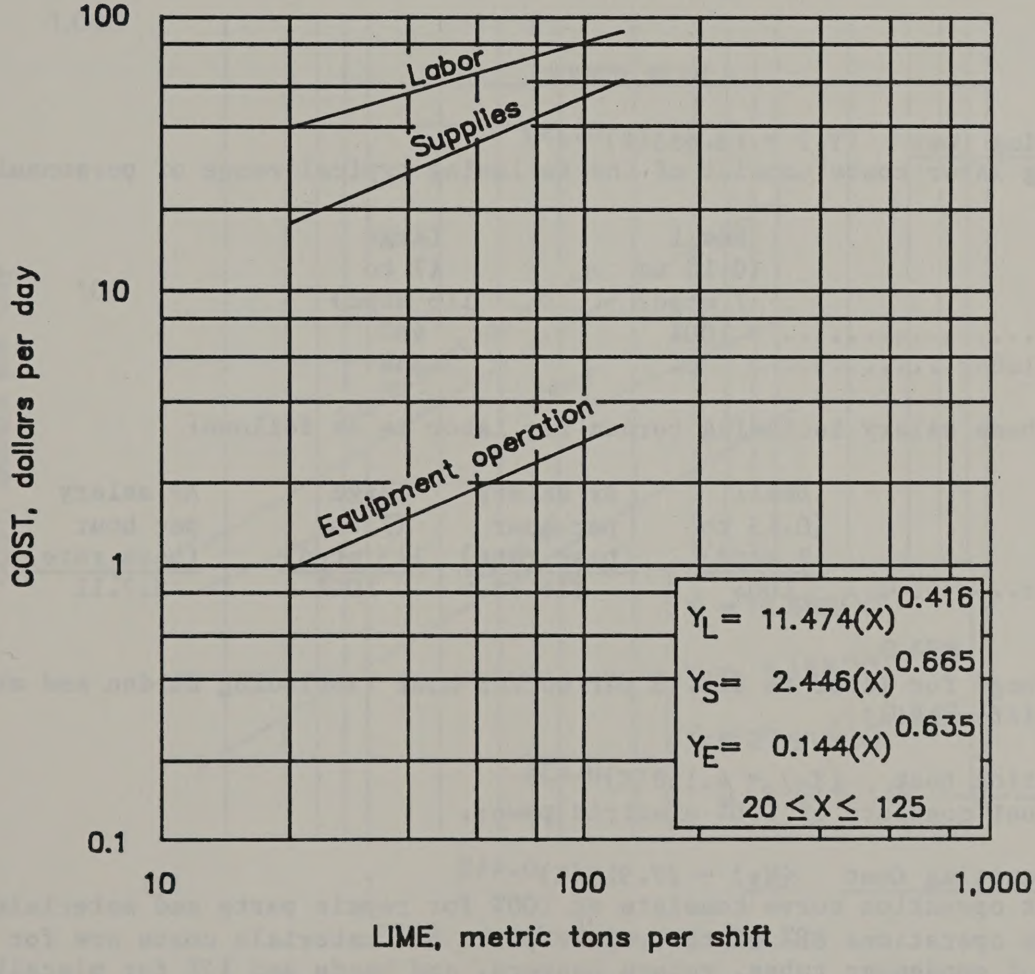
(S) Supply Operating Cost $(Y_S) = 2.446(X)^{0.665}$
The supply cost consists of 100% electric power. Grinding media consumption in the slaking mill is negligible and is not included in the supply operating cost.

(E) Equipment Operation Cost $(Y_E) = 0.144(X)^{0.635}$
The equipment operation curve consists of 100% for repair parts and materials. The curve includes an allowance for the replacement of pump parts.

ADJUSTMENT FACTOR

Shift Factor The curve is based on a one-shift-per-day operation. Typically, lime slaking circuits are operated primarily on day shift only. For a two- or three-shift operation, increase the operating costs proportionately.

Mineral Processing—Operating Costs



7.1.6.9. Lime slaking

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.10.1. MERCURY APPLICATIONS
MERCURY CONDENSERS

The operating cost curves for mercury condensers are given on a per day basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a capacity rate (X), in metric tons of feed material to the furnace per day. The curves are valid for operations between 0.15 and 115 mtpd. The mercury condenser is normally operated on a one-batch-per-day cycle for small operations. For large operations, it is assumed to be on a continuous basis.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 15.585(X)^{0.350}$
The operating labor costs consist of the following typical range of personnel:

	Small (0.15 to 7 mtpd)	Large (7 to 115 mtpd)
Direct labor................	100%	46%
Maintenance labor...........	0%	54%

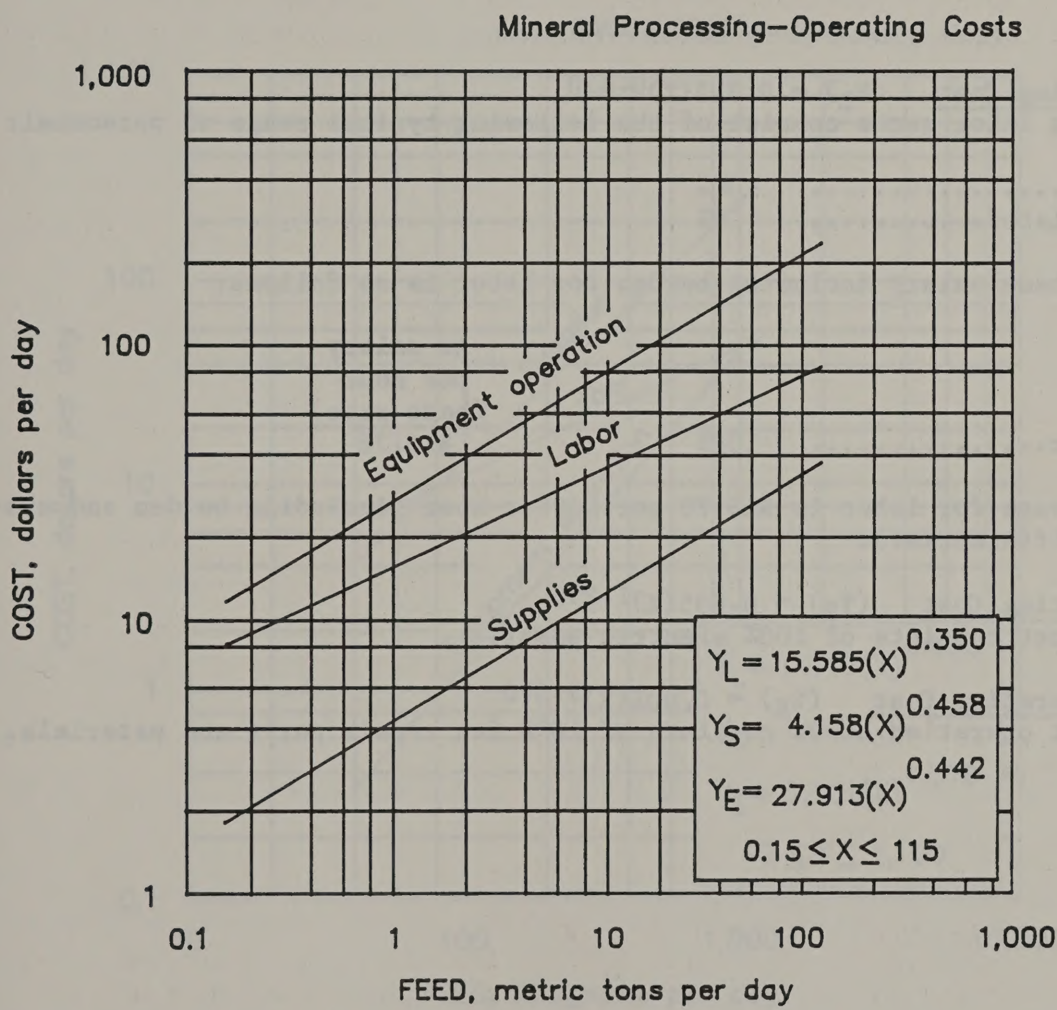
The average base salary including burden for labor is as follows:

	Small (0.15 to 7 mtpd)	Av salary per hour (base rate)	Large (7 to 115 mtpd)	Av salary per hour (base rate)
Mill operator..........	100%	$16.78	100%	$17.11

The average wage for labor is $16.95 per worker-hour (including burden and average shift differential).

(S) Supply Operation Cost $(Y_S) = 4.158(X)^{0.458}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 27.913(X)^{0.442}$
The equipment operation curve consists of 100% for repair parts and materials. For the large operations 88% of the repair parts and materials costs are for the replacement of condenser tubes, return hoppers, and bends and 12% for miscellaneous items.



7.1.6.10.1 Mercury applications
MERCURY CONDENSERS

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.10.2. MERCURY APPLICATIONS
MERCURY RETORTS

The operating cost curves for mercury retorts are given on a per day basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the feed rate (X), in kilograms feed per day. The curves are valid for operations between 40 and 1,100 kg/d, operating on a one-batch-per-day cycle.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.713(X)^{0.630}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	100%
Maintenance labor...........	0%

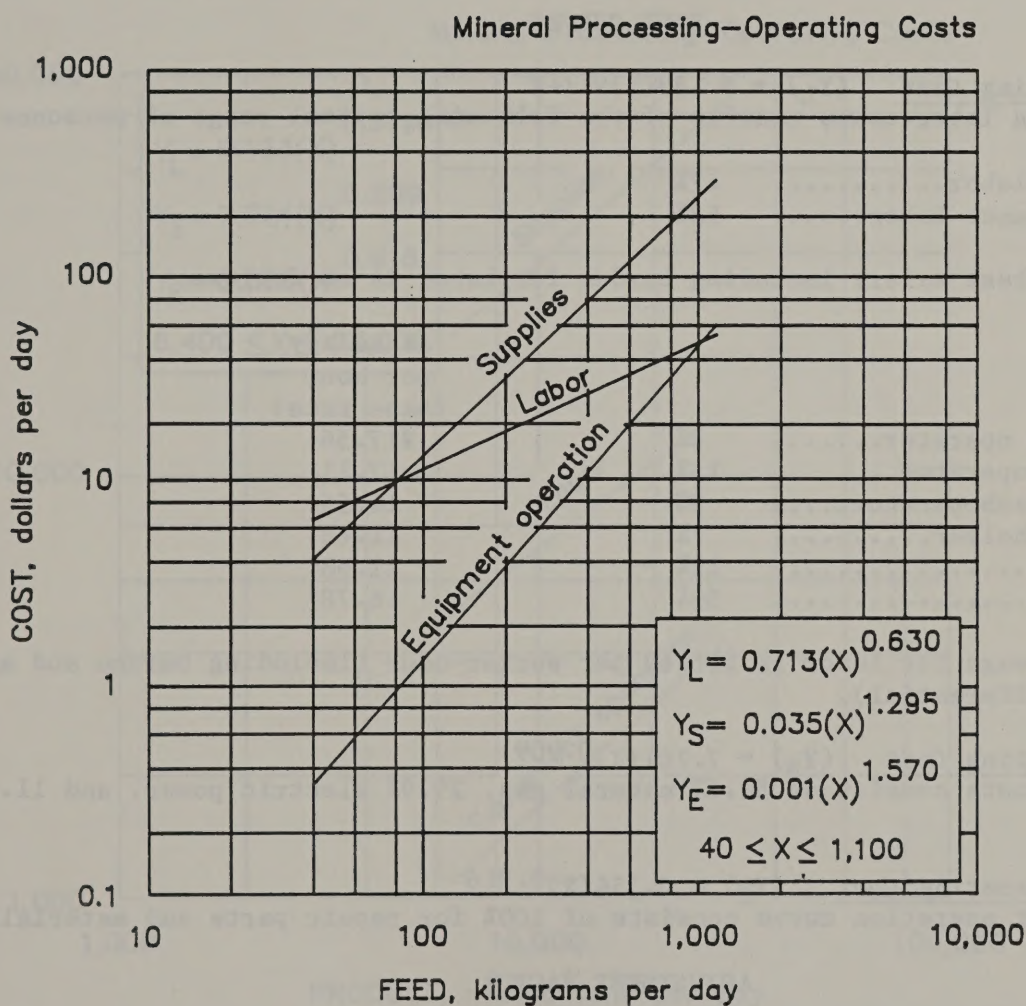
The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Mill operator...............	100%	$16.78

The average wage for labor is $16.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.035(X)^{1.295}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 0.001(X)^{1.570}$
The equipment operation curve consists of 100% for repair parts and materials.



7.1.6.10.2. Mercury applications
MERCURY RETORTS

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.11. PELLETIZING

The operating cost curves for pelletizing are given on a metric ton per day basis. The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the capacity rate (X), in metric tons of pellet production per day. The curves are valid for operations between 6,400 and 28,000 mtpd, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 9.133(X)^{0.719}$
The operating labor costs consist of the following typical range of personnel:

Direct labor...........	47%
Maintenance labor......	53%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Control room operator.......	4%	$17.56
Pelletizing operator........	15%	17.11
Pelletizing suboperator.....	9%	14.56
Pelletizing helper..........	7%	11.68
Laborer.....................	12%	11.68
Mechanic....................	53%	16.78

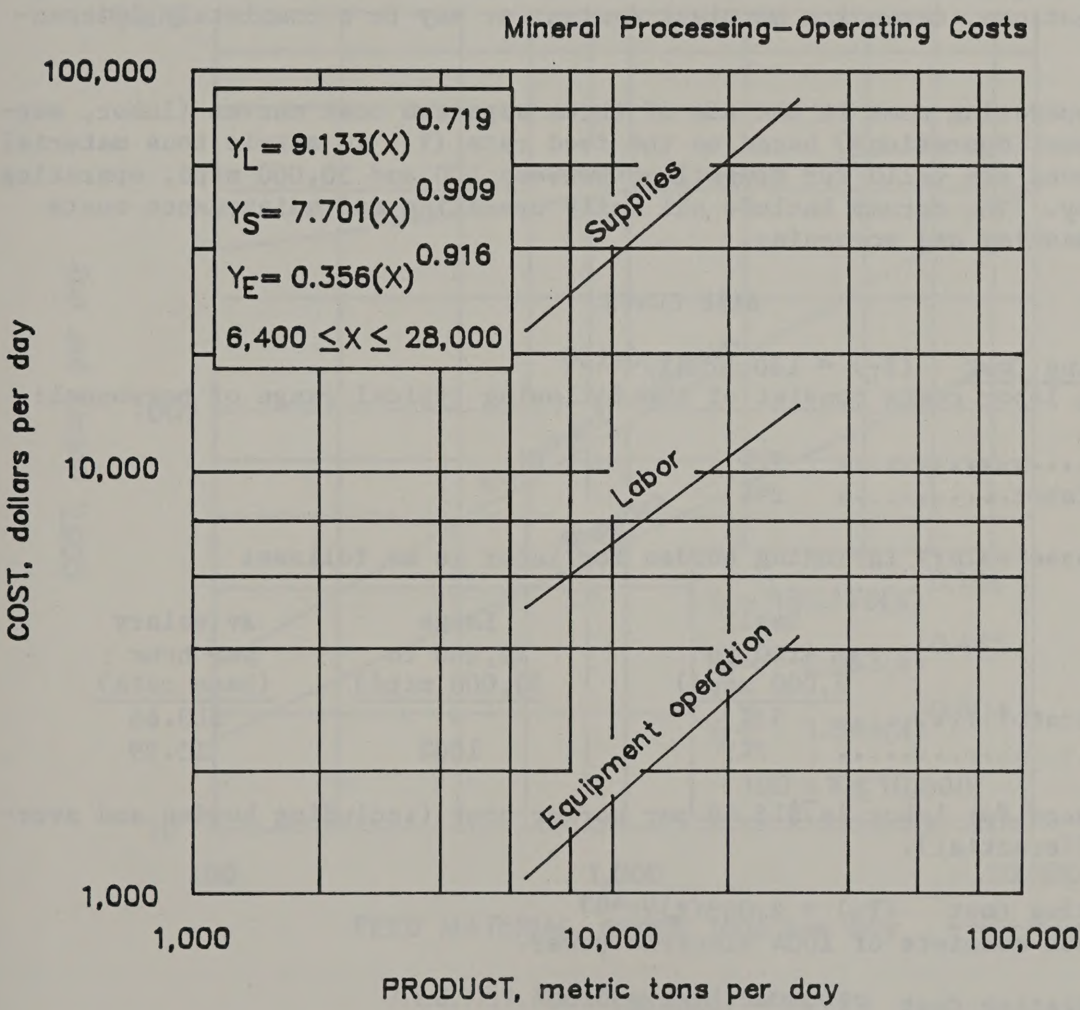
The average wage for labor is $15.69 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 7.701(X)^{0.909}$
The supply costs consist of 58.6% natural gas, 29.9% electric power, and 11.5% bentonite.

(E) Equipment Operating Cost $(Y_E) = 0.356(X)^{0.916}$
The equipment operation curve consists of 100% for repair parts and materials.

ADJUSTMENT FACTOR

Shift Factor The base curves are based on a three-shift-per-day operation. The pelletizing plant must be operated on a continuous basis to maintain a steady rate of feed to the indurating furnace. No adjustment factor for a one- or two-shift operation is recommended for pelletizing.



7.1.6.11. Pelletizing

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.12.1. WASHING AND SCREENING

This operation covers the cost of washing and screening loosely consolidated ores such as barite. Costs include the use of trommel screens, log washers, vibrating screens, water guns, and pumps. Washing separates the gangue from the ore, and screening separates the ore into two or more sizes. The sized ore is then usually processed further by various means. Washing is usually the first step as the ore enters the processing plant. Screening may be combined with crushing and grinding in various combinations, depending on plant design, or may be a completely independent operation.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operations) based on the feed rate (X), in metric tons material per day. The curves are valid for operations between 100 and 30,000 mtpd, operating two shifts per day. The curves include all daily operating and maintenance costs associated with washing and screening.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 130.175(X)^{0.150}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	71%
Maintenance labor...........	29%

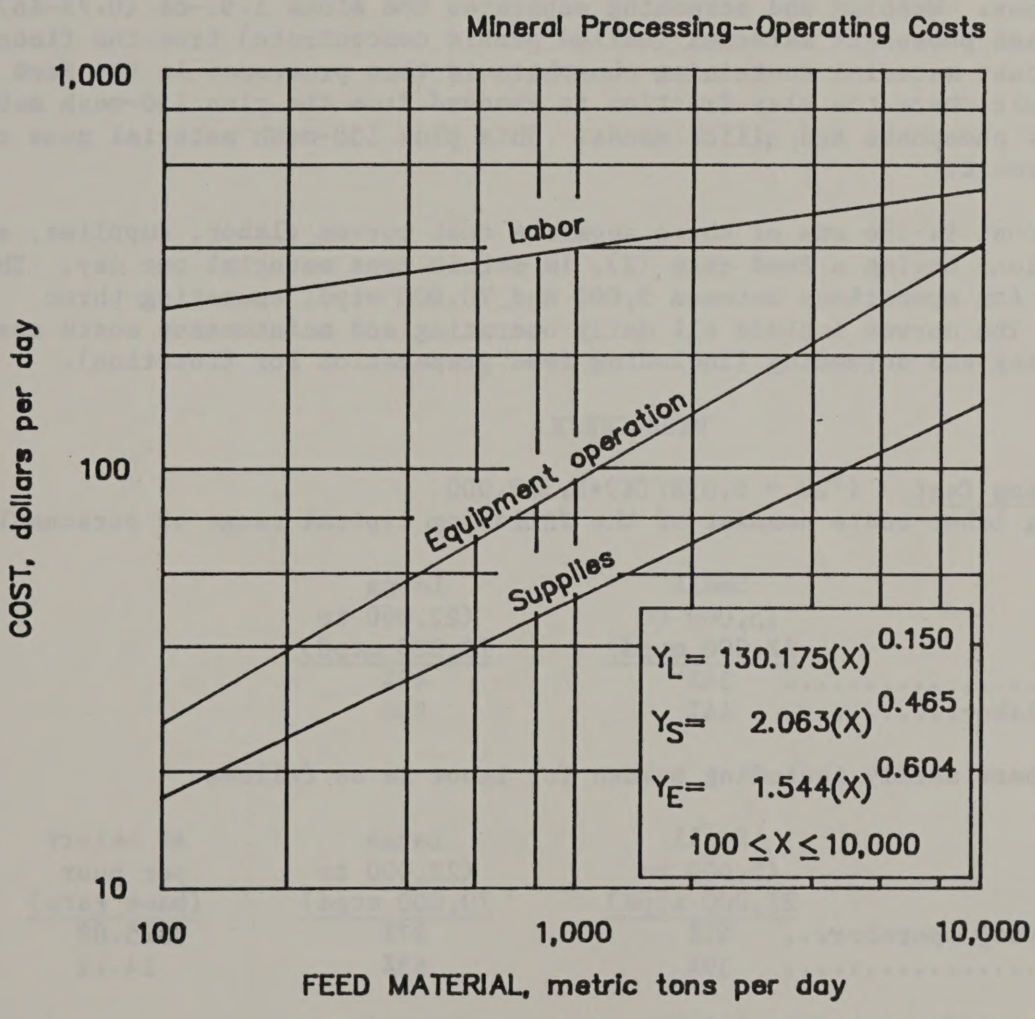
The average base salary including burden for labor is as follows:

	Small (100 to 2,000 mtpd)	Large (2,000 to 30,000 mtpd)	Av salary per hour (base rate)
Water-gun operator..........	93%	-	$13.66
Floor walker................	7%	100%	15.89

The average wage for labor is $15.48 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 2.063(X)^{0.465}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 1.544(X)^{0.604}$
The equipment operating costs consist of 93% for repair parts and 7% for lubricants. The equipment operation curve covers the daily operating cost for all trommel screens, log washers, vibrating screens, water guns, and pumps, and includes allowances for replacement and maintenance of log caps, wear plates, and trommel linings.



7.1.6.12.1. Washing and screening

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.6. SPECIAL APPLICATIONS

7.1.6.12.2. WASHING AND SCREENING PHOSPHATE

This operation covers the cost of washing and screening (including ore feed preparation for flotation) of loosely consolidated phosphate ores. Costs include the use of trommel screens, hammermills, log washers, flume and vibrating screens, classifiers, and cyclones. Washing and screening separates the minus 1.91-cm (0.75-in), plus 14- or 16-mesh phosphate material (called pebble concentrate) from the finer material. The finer material containing phosphate is then processed in the feed preparation circuit where the clay fraction is removed from the plus 150-mesh material consisting of phosphate and silica sands. This plus 150-mesh material goes to the flotation circuit.

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) having a feed rate (X), in metric tons material per day. The curves are valid for operations between 5,000 and 70,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with washing and screening (including feed preparation for flotation).

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.0547(X)+1,570.000$

The operating labor costs consist of the following typical range of personnel:

	Small (5,000 to 22,000 mtpd)	Large (22,000 to 70,000 mtpd)
Direct labor................	56%	45%
Maintenance labor...........	44%	55%

The average base salary including burden for labor is as follows:

	Small (5,000 to 22,000 mtpd)	Large (22,000 to 70,000 mtpd)	Av salary per hour (base rate)
Washer/feed prep operator...	61%	37%	$15.89
Laborer.....................	39%	63%	14.12

The average wage for labor is $15.20 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.00189(X)^{1.487}$

The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 1,304.820e^{0.0000284(X)}$

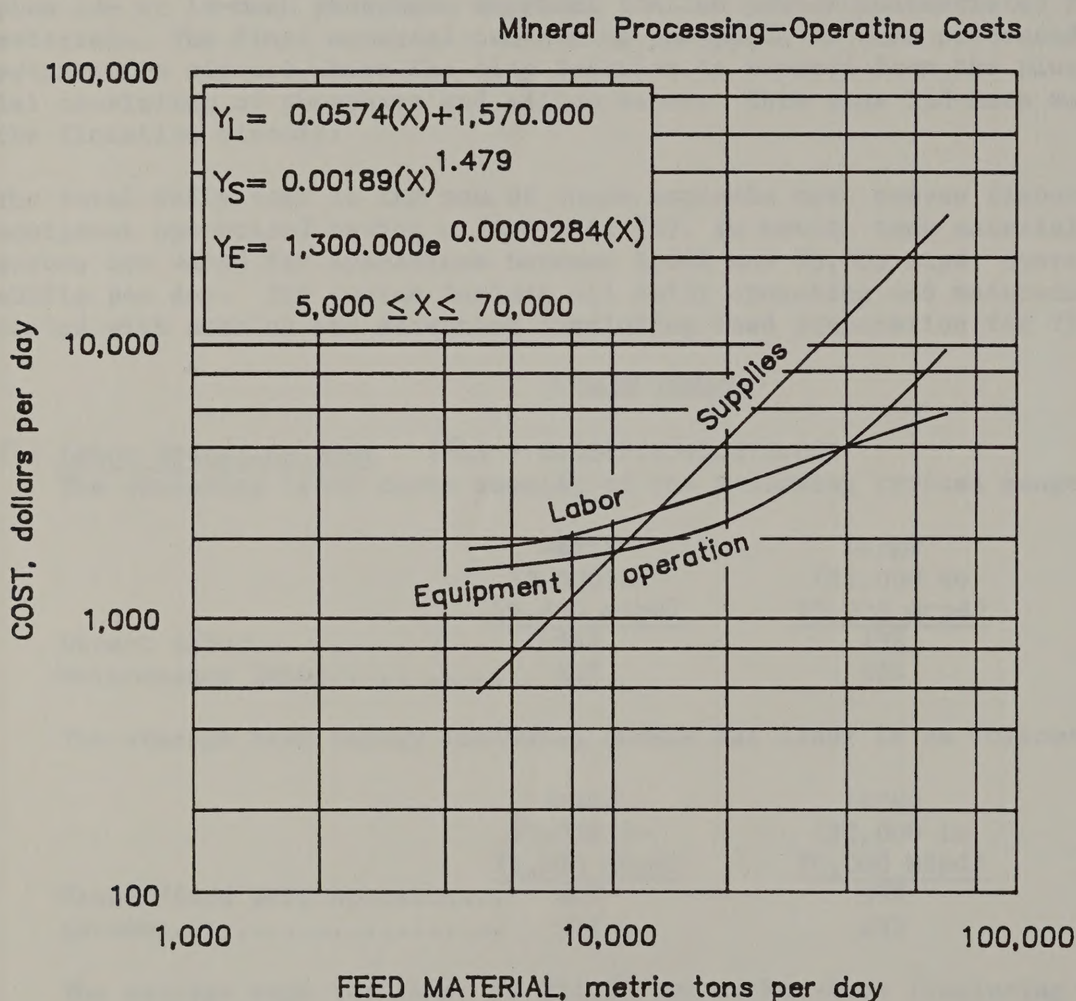
The equipment operation curve consists of 94% for repair parts and 6% for lubricants. The curve covers the daily operating cost for all screens, cyclones, and pumps, and for pipe replacement.

ADJUSTMENT FACTOR

<u>Polyurethane Liner Factor</u> If polyurethane liners for screens, pumps, cyclones, and other equipment within the washing and screening circuit are utilized to reduce excessive abrasion by the ore, multiply the cost obtained from the maintenance portion of the labor curve by the following factor:

Labor factor $(F_L) = 0.75$

The equipment operations curve is not affected because the increased cost of polyurethane liners offsets the cost saved by increased wear life.



7.1.6.12.2. Washing and screening
PHOSPHATE

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.7. TRANSPORTATION

7.1.7.3. LONG-DISTANCE BARGE HAULAGE

Shipping large tonnage commodities by barge can be an effective method of transportation if access points are available and high speed is not important. It is even possible to ship mineral materials a short distance by rail and then transfer the material to barge and still save money over rail haulage alone.

With the deregulation of the barge industry, there has been an increase in competition and a decrease in the number of operators. Those companies still operating have found themselves overequipped for the amount of material that is presently being hauled.

As of January 1984, typical costs for transportation of bulk cargoes have been between $0.0027 and $0.0030 per metric ton kilometer, with the average cost being near $0.0028 per metric ton kilometer.

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.7. TRANSPORTATION

7.1.7.4. LONG-DISTANCE RAIL HAULAGE

The following tabulation gives the average cost, in cents per metric ton-kilometer, for shipping mineral materials from the Mountain-Pacific territorial area (including Denver, CO), to any of the five territorial areas within the continental United States. This information is valid as of January 1984.

AVERAGE SHIPPING COSTS FOR MINERAL MATERIALS, cents per metric ton-kilometer

Material shipped from Mountain-Pacific area	Area destination					
	Mountain-Pacific	Western	South-western	Southern	Official	U.S. average
Metallic ores	2.53	1.04[e]	2.87[e]	NA	NA	2.33
Iron concentrates	1.47	1.04[e]	NA	NA	NA	1.47
Copper precipitates	3.01	NA	NA	NA	NA	3.01
Bauxite ore	2.65	NA	2.91[e]	NA	NA	2.67
Alumina calcine	2.66	NA	2.87[e]	NA	NA	2.66
Nonmetallic minerals[1]	2.94	1.55	2.18	1.96	2.02	2.68
Crushed stone	4.13	NA	NA	NA	NA	4.11
Sand or gravel	2.73	4.75	NA	NA	NA	2.74
Industrial sand	2.54	1.01[e]	1.68[e]	NA	NA	2.54
Refractories	1.83	NA	NA	1.89	NA	1.85
Clay minerals	2.94	NA	NA	1.89	NA	2.37
Fertilizer minerals	3.47	2.65	1.49	2.05	2.25	2.09
Borate, crude	3.39	2.85	NA	1.89	NA	2.67
Sulfur	3.82	3.09	1.99	2.12	2.62	2.34
Gypsum crude	3.30	NA	NA	NA	NA	3.30
Diatomaceous earth	4.31	2.03	2.05	2.31	2.32	2.22
Nonmetallic minerals n.e.c.[2]	2.35	1.84	1.49	1.58	1.47	1.63
Coal	1.87	1.25	1.13	1.30	1.33	1.26

[e]Estimated. NA Not available.
[1]Most nonmetallic ores, except fuels.
[2]Includes agate, crude chalk, lithium, earth or soil, coral, rubidium, graphite, sericite, nepheline syenite, shale, well drilling cores, crude topaz, vermiculite-unexpanded, slag, perlite, cornwall, crystal quartz rock, quartzite, silaceous fluxing ore, silica rock, and zeolites.

Source: 1983 Carload Waybill Sample data collected by Dep. of Transportation, Federal Railroad Administration, Office of Conrail.

For example, copper precipitates traditionally are never shipped out of the Mountain-Pacific area.

To determine the total cost of transporting a specific mineral material, first select the appropriate cost from the tabulation, then multiply that value by the distance, in kilometers, the material is to be shipped, and also by the metric tonnage to be shipped. Finally, divide the answer by 100 to get a value in dollars.

Example: The cost for shipping 100,000 mt of fertilizer minerals from Denver, CO, to a point in the Southern Area, 2,500 km away, is

$$[(2.05¢/\text{mt}\cdot\text{km}) \times (100{,}000\text{mt}) \times (2{,}500\text{km})/(100¢/\$) = \$5{,}125{,}000$$

The following map shows the boundaries for the different territorial areas.

To estimate the cost for shipping mineral materials from one point to another, irrespective of territorial zones, use the following equation:

$$Y = [15.359(D)^{-0.275}]/100$$

where D = distance the material is to be shipped, in kilometers,
and Y = cost, in cents per metric ton kilometer.

The resultant answer must be multiplied by the tonnage and the distance it is to be hauled to get a total cost in dollars.


WESTERN
MOUNTAIN-PACIFIC
OFFICAL
SOUTHERN
SOUTHWESTERN

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.7. TRANSPORTATION

7.1.7.5. LONG-DISTANCE SURFACE CONVEYOR

These curves cover the cost of transporting material from the mine via a single-flight conveyor belt reinforced with high-strength steel and cover a capacity range of 15,000 to 150,000 mtpd. The material is conveyed up a 10^{o} slope for a distance of 1 Km. The conveyor availability is 94%. Usually, the material is crushed or screened at the mine site before being conveyed. Screen and crusher costs are not included in this cost but are covered in separate sections.

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons material transported per day. The curves are valid for operations between 15,000 and 150,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with the conveyor operation.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 7.429(X)^{0.464}$
The operating labor costs are distributed as follows:

	Small (15 to 50,000 mtpd)	Large (50,000 to 150,000 mtpd)
Direct labor................	71%	47%
Maintenance labor...........	29%	53%

The direct labor costs consist of the following typical range of personnel:

	Small (15 to 50,000 mtpd)	Large (50,000 to 150,000 mtpd)	Av salary per hour (base rate)
Operator...................	64%	54%	$16.25
Assistant operator..........	36%	46%	13.97

The average wage for labor is $15.32 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.068(X)^{0.933}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 2.226(X)^{0.358}$
The equipment operating cost consists of 95% for repair parts and 5% for lubrication for the idlers and mechanical parts.

ADJUSTMENT FACTOR

Length and Slope Factor To determine costs for varying conveyor lengths and slopes, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.815+0.190(L)$

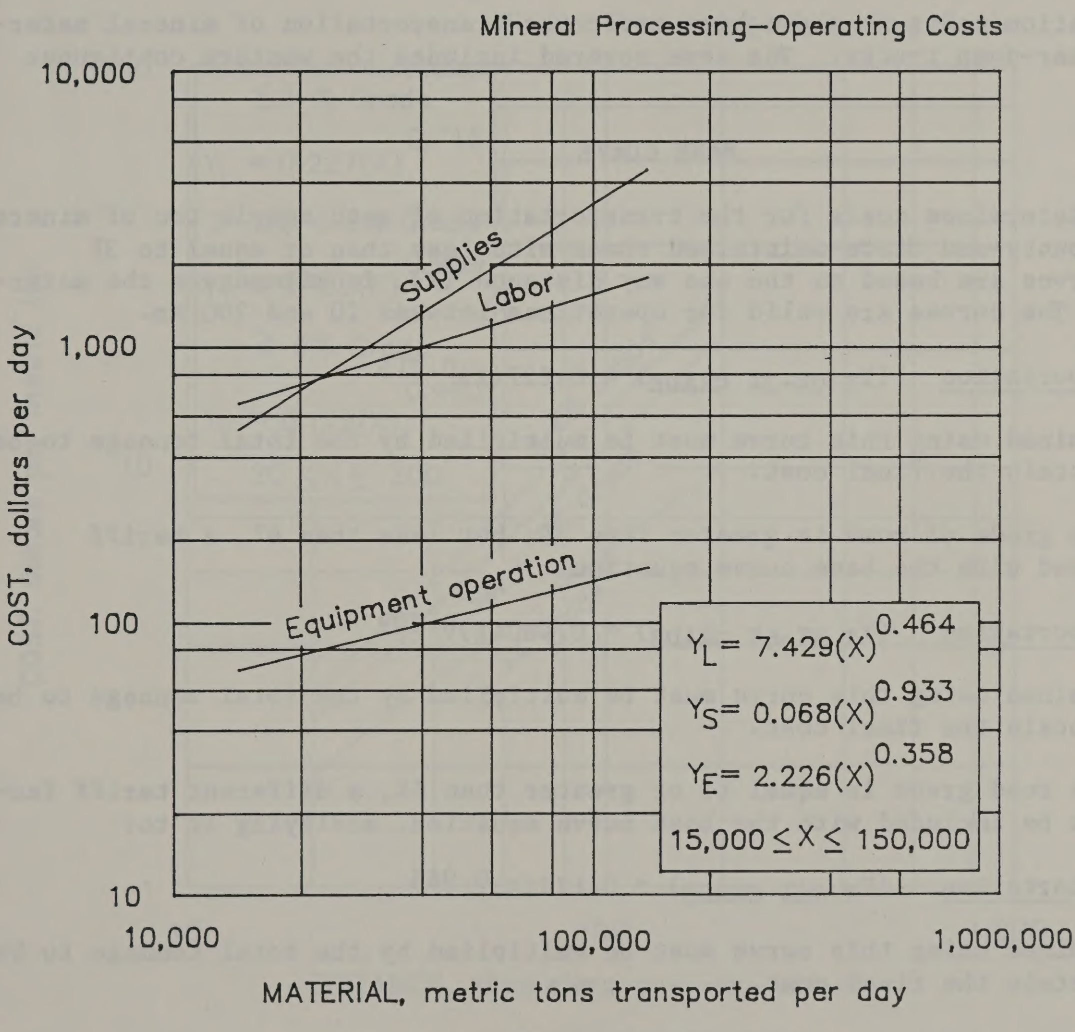
Supply factor $(F_S) = [0.208+0.0794(S)][L]$

Equipment operation factor $(F_E) = L$

where L = length of conveyor, in kilometers,

and S = slope of conveyor, in degrees (S is between 0° and 15°).

The cost for a decline conveyor is equal to that for a horizontal conveyor (0° slope).



7.1.7.5. Long distance surface conveyor

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.7. TRANSPORTATION

7.1.7.6. LONG-DISTANCE TRUCK HAULAGE

The trucking industry has undergone intensive change since its recent deregulation. Truck transportation of mineral materials has shifted predominantly away from the class rate system to the bulk commodity method. This has corresponded with a decrease in the number of carriers and an increase in competition. Each carrier now determines his or her own rate and tariff schedules.

Truck transportation costs as shown here cover the transportation of mineral materials by 23 mt rear-dump trucks. The area covered includes the western contiguous United States.

BASE CURVE

The base curve determines costs for the transportation of each metric ton of mineral materials via county-and State-maintained roads with less than or equal to 3% grades. The curves are based on the one way distance (X), in kilometers the material is hauled. The curves are valid for operations between 20 and 200 Km.

(T) Truck transportation $(Y_{T\ 0\%-3\%\ GRADE}) = 0.227(X)^{0.715}$

Costs determined using this curve must be multiplied by the total tonnage to be hauled to obtain the final cost.

When the average grade of road is greater than 3%, but less than 6%, a tariff factor is included with the base curve equation.

(T) Truck transportation $(Y_{T\ 3\%-6\%\ GRADE}) = 0.180(X)^{0.909}$

Costs determined using this curve must be multiplied by the total tonnage to be hauled to obtain the final cost.

When the average road grade is equal to or greater than 6%, a different tariff factor will have to be included with the base curve equation, modifying it to:

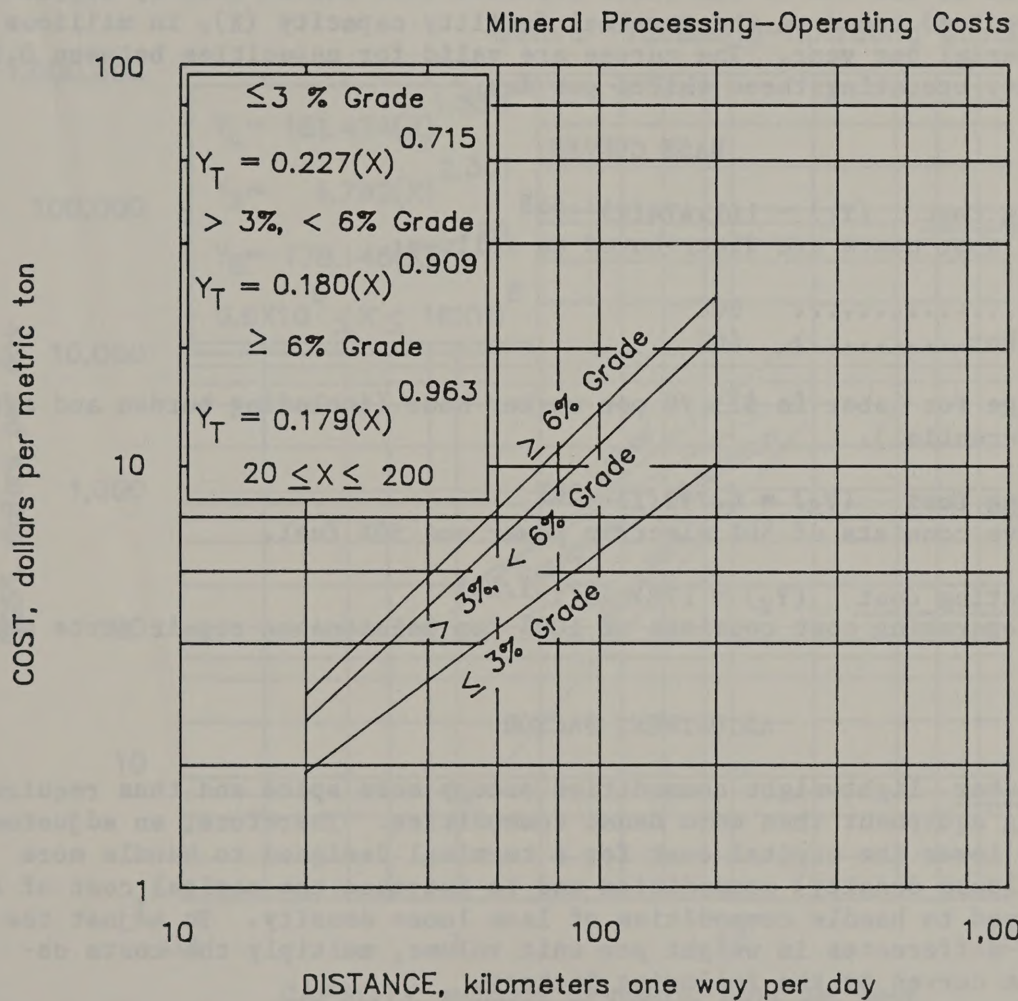
(T) Truck transportation $(Y_{T\ +6\%\ GRADE}) = 0.179(X)^{0.963}$

Costs determined using this curve must be multiplied by the total tonnage to be hauled to obtain the final cost.

ADJUSTMENT FACTORS

Long-Term Contract The final values arrived at through multiplying the tonnage by any of the three curves can be reduced by 10% to 20% if long-term hauling contracts are to be used.

Tonnage If trucks with carrying capacities greater or less than 23 mt are used, the cost per metric ton should be modified accordingly.



7.1.7.6. Long distance truck haulage

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.7. TRANSPORTATION

7.1.7.7. MARINE TERMINAL

Costs derived from these curves apply to the operation of a deep-water, export bulk ore marine terminal. Operation cost does not reflect actual terminal charges, but actual costs for railcar or barge receiving, open storage (approximately 10% of the annual throughput), reclaiming, and shiploading.

The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) based on the terminal facility capacity (X), in millions of metric tons of material per year. The curves are valid for capacities between 0.9 and 16.0 million mt, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 161.474(X)^{1.558}$
The operating labor costs are distributed as follows:

Direct labor................	60%
Maintenance labor...........	40%

The average wage for labor is $15.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 4.792(X)^{2.301}$
The supply curve consists of 50% electric power and 50% fuel.

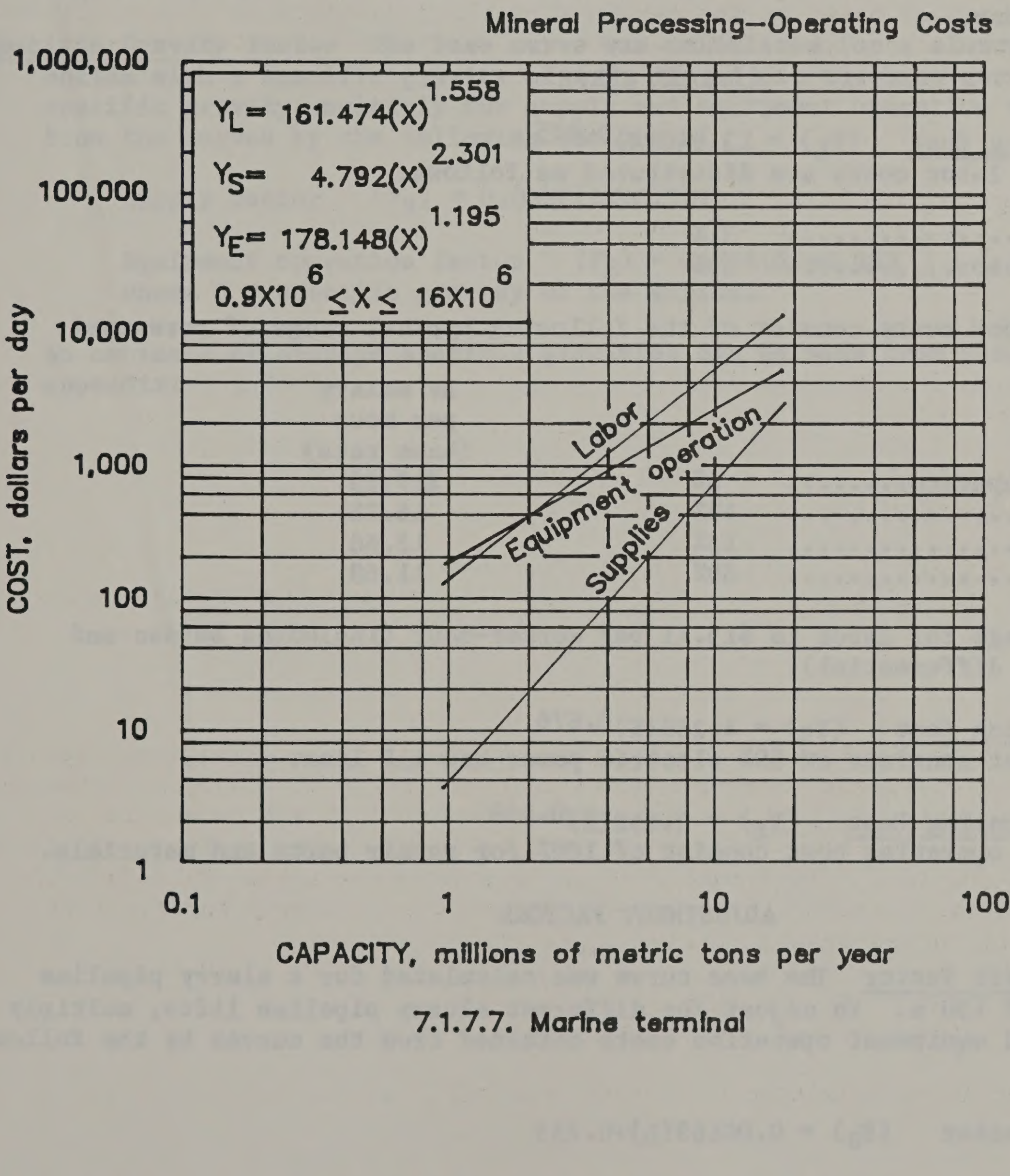
(E) Equipment Operating Cost $(Y_E) = 178.148(X)^{1.195}$
The equipment operating cost consists of 100% for maintenance repair parts and materials.

ADJUSTMENT FACTOR

Density (Loose) Factor Lightweight commodities occupy more space and thus require larger handling equipment than more dense commodities. Therefore, an adjustment is required to lower the capital cost for a terminal designed to handle more dense (higher loose density) commodities and to increase the capital cost of a terminal designed to handle commodities of less loose density. To adjust the base curve for differences in weight per unit volume, multiply the costs obtained from the curves by the following factor:

Density factor $(Y_D) = 3.418(D)^{-0.167}$
where D = loose density, in kilograms per cubic meter.

An estimate of loose density can be made from table A-2 in the appendix.



7.1.7.7. Marine terminal

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.7. TRANSPORTATION

7.1.7.8. SLURRY PIPELINE

The operating cost curves for slurry pipeline cover the cost of transporting a slurry. The base curves are based on a slurry pipeline of 10 Km in length with a lift of 150 m pumping solids at specific gravity of 4.3. The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) at an adjusted feed rate (X), in metric tons material transported per day. The curves are valid for operations between 900 and 32,000 mt, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 13.940(X)^{0.445}$
The operating labor costs are distributed as follows:

Direct labor................	31%
Maintenance labor...........	69%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Control room operator.......	6%	$17.23
Mill operator...............	49%	16.78
Mill helper.................	15%	13.66
Mill laborer................	30%	11.68

The average wage for labor is $15.11 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 4.259(X)^{0.676}$
The supply cost consists of 89% electric power and 11% lime.

(E) Equipment Operating Cost $(Y_E) = 3.652(X)^{0.458}$
The equipment operating cost consist of 100% for repair parts and materials.

ADJUSTMENT FACTORS

Slurry Pipeline Lift Factor The base curve was calculated for a slurry pipeline with a lift of 150 m. To adjust for different slurry pipeline lifts, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.00163(L)+0.755$

Equipment operation factor $(F_E) = 0.00104(L)+0.844$
where L = lift, in meters.

Slurry Pipeline Length Factor The base curve was calculated for a slurry pipeline of 10 km in length. To adjust for different slurry pipeline lengths, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.0026(P)+0.974$

Supply factor $(F_S) = 0.0172(P)+0.828$

Equipment operation factor $(F_E) = 0.011(P)+0.890$
where P = length of pipeline, in kilometers.

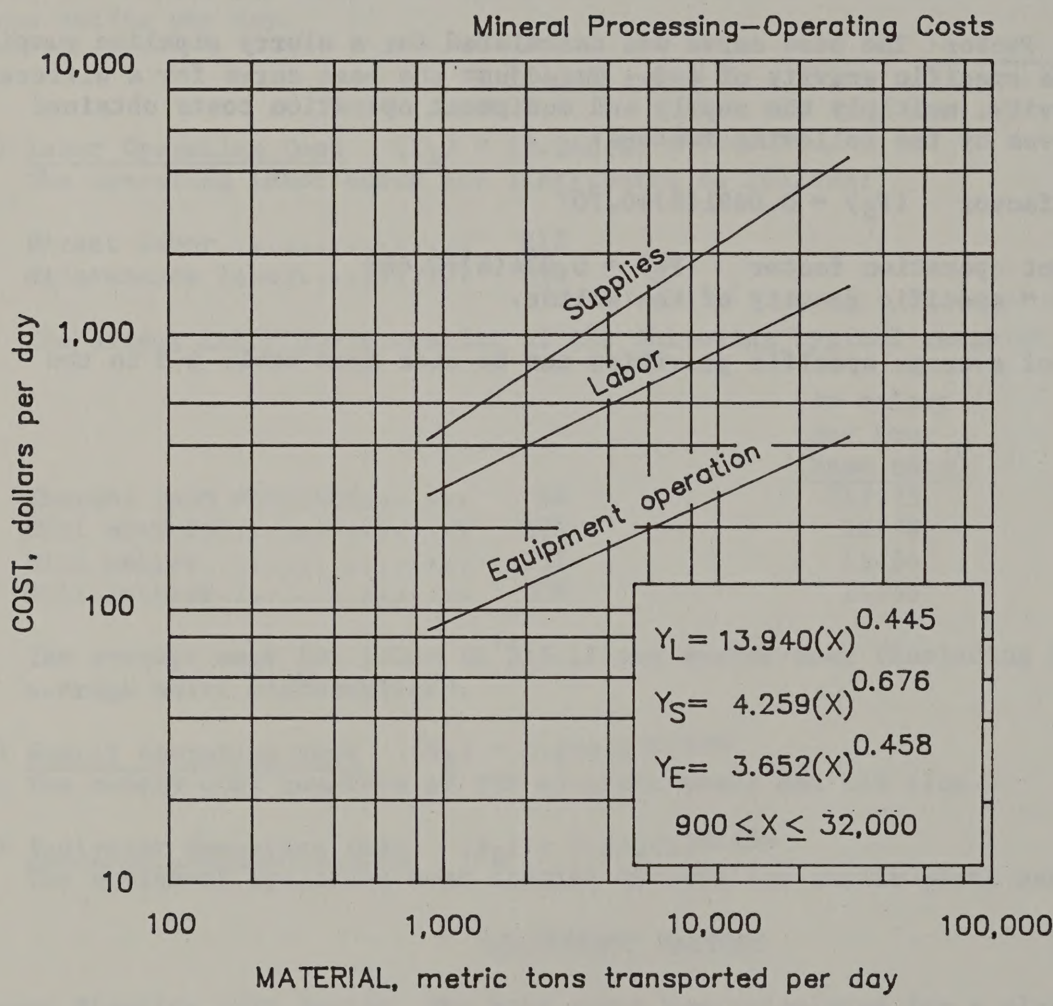
An estimate of average pipeline lengths can be made from table A-3 in the appendix.

Specific Gravity Factor The base curve was calculated for a slurry pipeline pumping solids with a specific gravity of 4.3. To adjust the base curve for a different specific gravity, multiply the supply and equipment operation costs obtained from the curves by the following factors:

Supply factor $(F_S) = 0.0681(S)+0.707$

Equipment operation factor $(F_E) = 0.074(S)+0.683$
where S = specific gravity of the solids.

An estimate of average specific gravities can be made from table A-3 in the appendix.



7.1.7.8. Slurry pipeline

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.8. GENERAL OPERATIONS

7.1.8.2. COMPRESSED AIR FACILITIES

These curves cover the use of compressed air in mineral processing plants. Low-pressure air is used in flotation, and high-pressure air is used for controls and general use.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the capacity (X), in metric tons processing plant feed per day. The curves are valid for operations between 100 and 100,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with producing compressed air.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 6.093(X)^{0.284}$
The air compressor has no operator assigned to it.

The operating labor costs consist of the following typical range of personnel:

Direct labor................	0%
Maintenance labor...........	100%

The average base salary including burden for labor is as follows:

		Av salary per hour (base rate)
Mechanic....................	100%	$17.11

The average wage for labor is $17.11 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 9.591(X)^{0.232}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 15.894(X)^{0.269}$
The equipment operating curve covers the daily operating cost for all compressor equipment and consists of 92% for repair parts and 8% for lubricants.

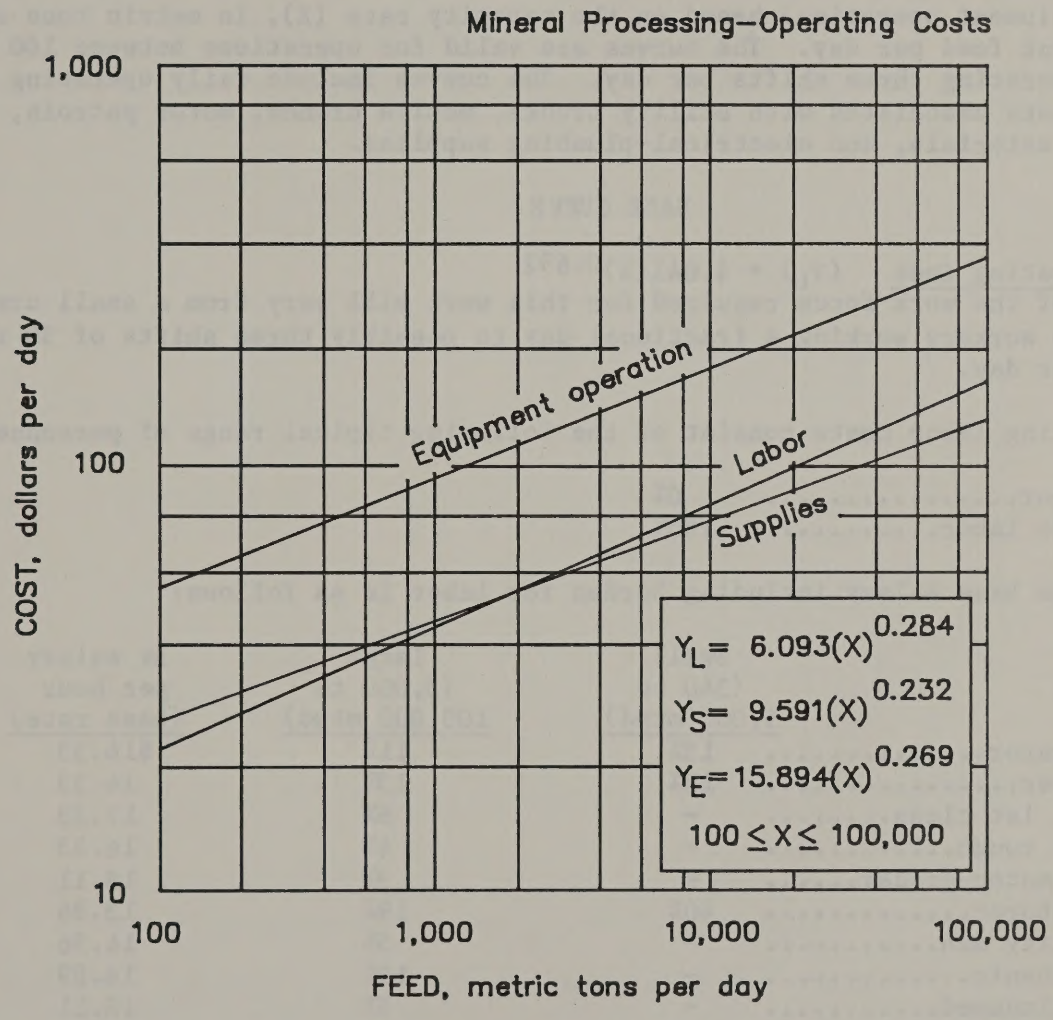
ADJUSTMENT FACTOR

<u>Elevation Factor</u> If elevation of the compressor plant varies from 1,600 m, a correction for altitude must be applied to the air requirements. To adjust air volume requirements if the plant is not at 1,600 m elevation, multiply the costs obtained from the curves by the following factor:

Elevation,			Elevation,		
ft	m	Factor	ft	m	Factor
0	0	0.85	6,000	1,831	1.03
1,000	305	0.87	7,000	2,136	1.07
2,000	610	0.90	8,000	2,441	1.11
3,000	915	0.93	9,000	2,746	1.15
4,000	1,220	0.96	10,000	3,050	1.19
5,000	1,526	0.99	12,500	3,813	1.31
5,249	1,600	1.00			

The factors can be generated from the following equation:

Elevation factor $(F_E) = 0.823+0.0001(G)$
where G = elevation, in meters.



7.1.8.2. Compressed air facilities

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.8. GENERAL OPERATIONS

7.1.8.5. GENERAL ITEMS--COMMUNICATIONS, SANITATION, HOUSEKEEPING, FIRE PROTECTION, AND ELECTRICAL

This set of curves covers the cost of general yard work, carpentry repair, janitorial services, plumbing, road grading, ditch cleaning, general mechanical repairs, handling incoming supplies and materials, electrical maintenance and repair, and general housekeeping.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the capacity rate (X), in metric tons of processing plant feed per day. The curves are valid for operations between 100 and 100,000 mt, operating three shifts per day. The curves include daily operating and maintenance costs associated with utility trucks, mobile cranes, motor patrols, various cleaning materials, and electrical-plumbing supplies.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 4.041(X)^{0.692}$

The size of the work force required for this work will vary from a small crew of one or two workers working a fractional day to possibly three shifts of 50 to 60 workers per day.

The operating labor costs consist of the following typical range of personnel:

Direct labor................	0%
Maintenance labor...........	100%

The average base salary including burden for labor is as follows:

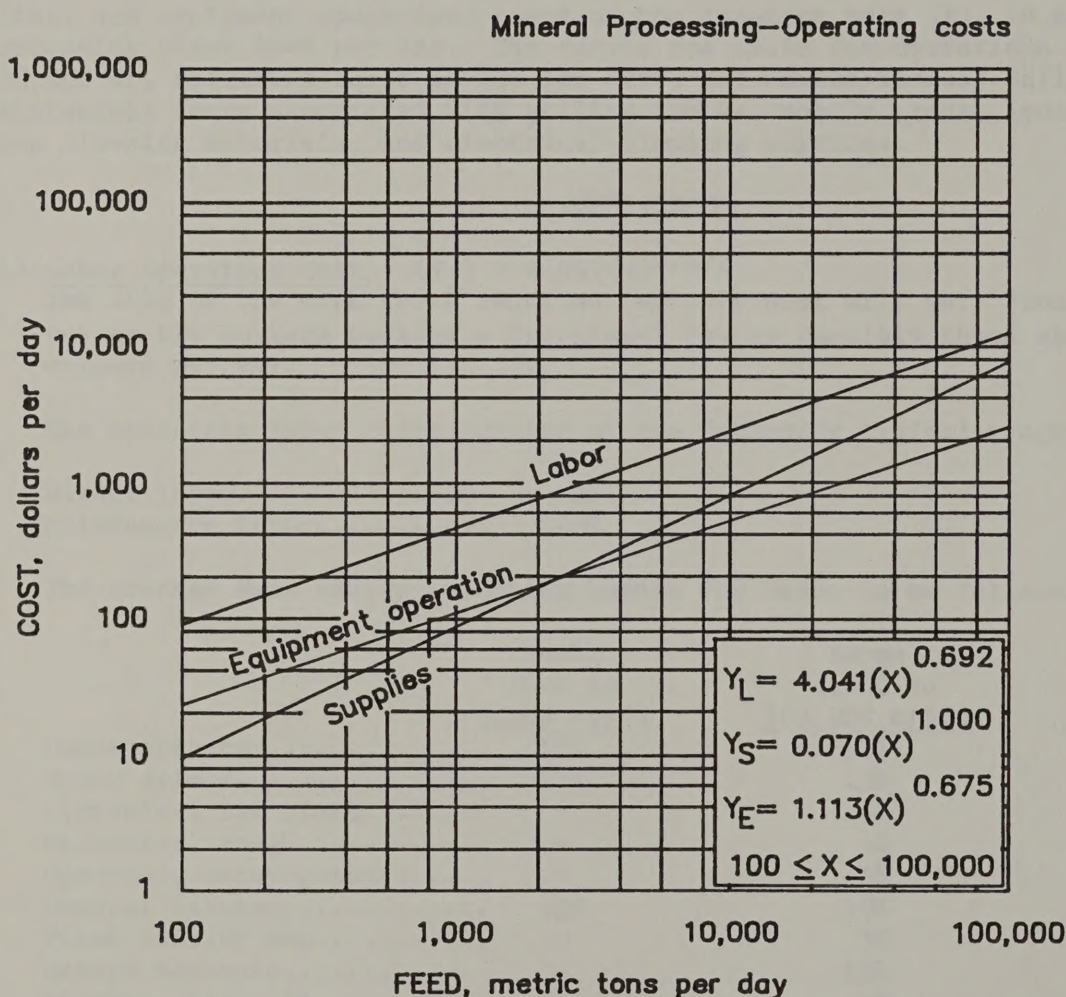
	Small (340 to 5,000 mtpd)	Large (5,000 to 100,000 mtpd)	Av salary per hour (base rate)
Crane operator.............	15%	11%	$16.33
Truck driver...............	15%	13%	16.33
Carpenter, 1st class........	-	6%	17.23
Carpenter, rough............	-	4%	16.33
Operator, motor-grader......	-	3%	18.11
General laborer.............	40%	19%	13.86
Plant utility man...........	-	5%	14.56
Garage mechanic.............	-	13%	16.89
Plumber, licensed...........	-	5%	18.11
Welder, 1st class...........	15%	10%	16.78
Electrician.................	15%	11%	16.78

The average wage for labor is $16.13 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.070(X)^{1.000}$

The supply cost consists of 100% miscellaneous supplies priced at $0.070 per metric ton of mineral processing plant feed.

(E) Equipment Operating Cost $(Y_E) = 1.113(X)^{0.675}$
The equipment operating cost consists of 32% for repair parts and 62% for fuel and lubricants, and 6% for tires.



7.1.8.5. General items
COMMUNICATIONS, SANITATION, HOUSEKEEPING,
FIRE PROTECTION, AND ELECTRICAL

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.8. GENERAL OPERATIONS

7.1.8.6.1. LOADING FACILITIES
LOAD-OUT FACILITIES

The load-out operating costs represented are only applicable for concentrates stored using a conveyor, bucket elevator, and elevated storage bin system. The storage bins are capable of holding a 2-day supply of mill concentrate output, and are emptied every other day into 45-mt trucks or 90 mt railcars for delivery to the smelter. An example of the type of materials stored would be copper or molybdenum concentrates.

The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) having on a production rate (X), in metric tons of concentrate transferred from a mill to storage bins in a 24-h period. The curves are valid for operations between 150 and 1,500 mtpd, operating one shift per day.

BASE CURVES

(L) Labor Operating Costs $(Y_L) = 71.565(X)^{0.145}$
The operating labor costs are distributed as follows:

Direct labor................	84%
Maintenance labor...........	16%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Mechanic....................	42.9%	$17.99
Conveyor operator...........	30.2%	14.89
Laborer.....................	26.9%	13.26

The average wage for labor is $15.78 per worker-hour (including burden and average shift differential).

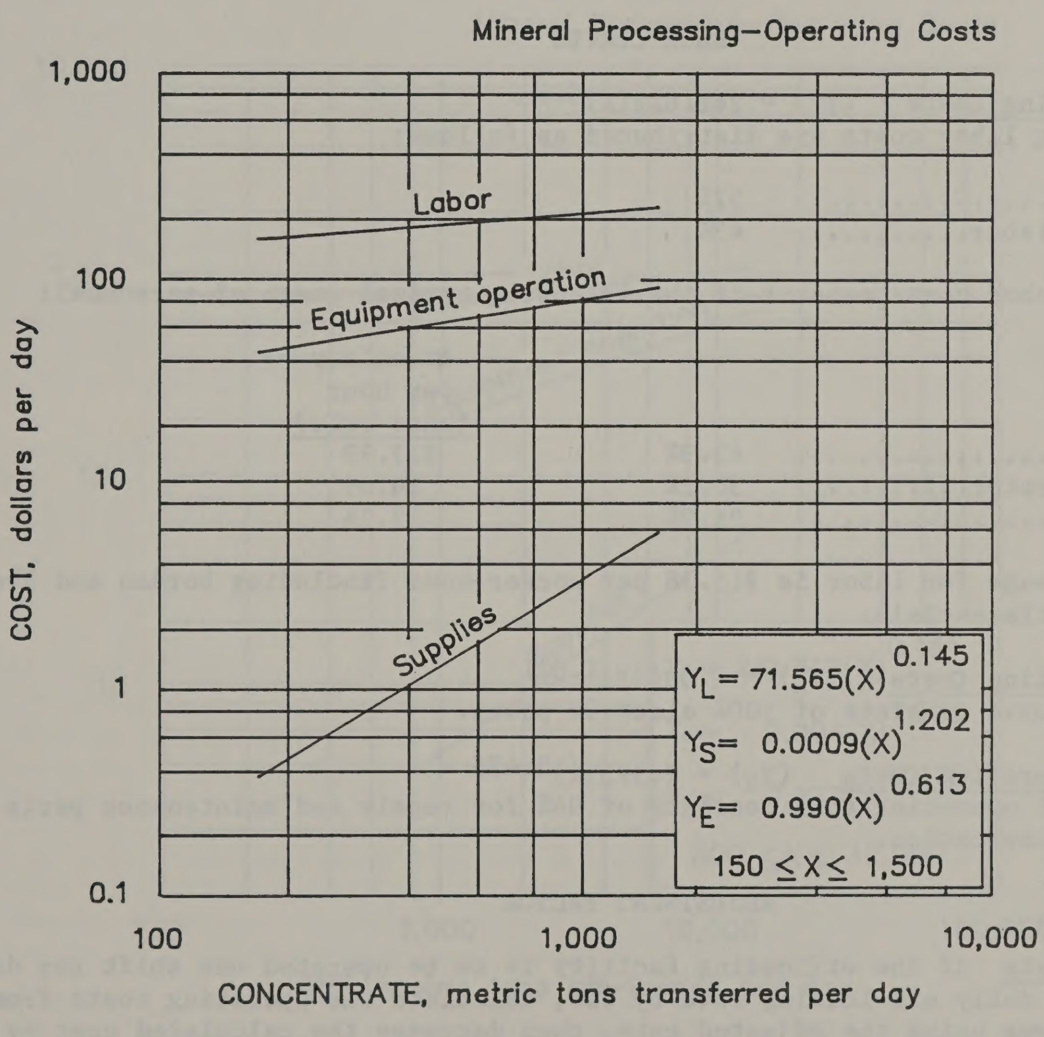
(S) Supply Operating Costs $(Y_S) = 0.0009(X)^{1.202}$
The supply curve consists of 100% electric power.

(E) Equipment Operating Costs $(Y_E) = 0.990(X)^{0.613}$
The equipment operating cost consists of 94% for repair and maintenance parts and 6% for lubrication.

ADJUSTMENT FACTORS

Secondary Mineral Recovery Operating costs for the recovery of secondary minerals are not included in this section. If such operations are considered, appropriate adjustments should be made to the cost curves.

Shift Factor Planned use of offloading equipment is considered to occur intermittently throughout the 24-h work day as concentrates in adequate quantities are made available from the mill for transportation to the storage bins. If the operations occur for periods of time 110% greater than or 70% less than 9 h/d, suitable adjustments must be made to the cost curves.



7.1.8.6.1. Loading facilities
LOAD–OUT FACILITIES

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.8. GENERAL OPERATIONS

7.1.8.6.2. LOADING FACILITIES
OFF-LOADING FACILITIES

The total daily cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) having on a production rate (X), in metric tons of ore off-loaded and stored in bins for use by the mill per day. The curves are valid for operations between 800 and 12,000 mtpd, operating two shifts per day.

BASE CURVES

(L) Labor Operating Costs $(Y_L) = 241.612(X)^{0.161}$
The operating labor costs are distributed as follows:

Direct labor................	57%
Maintenance labor...........	43%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Mechanic....................	42.9%	$17.99
Conveyor operator...........	30.2%	14.89
Laborer.....................	26.9%	13.26

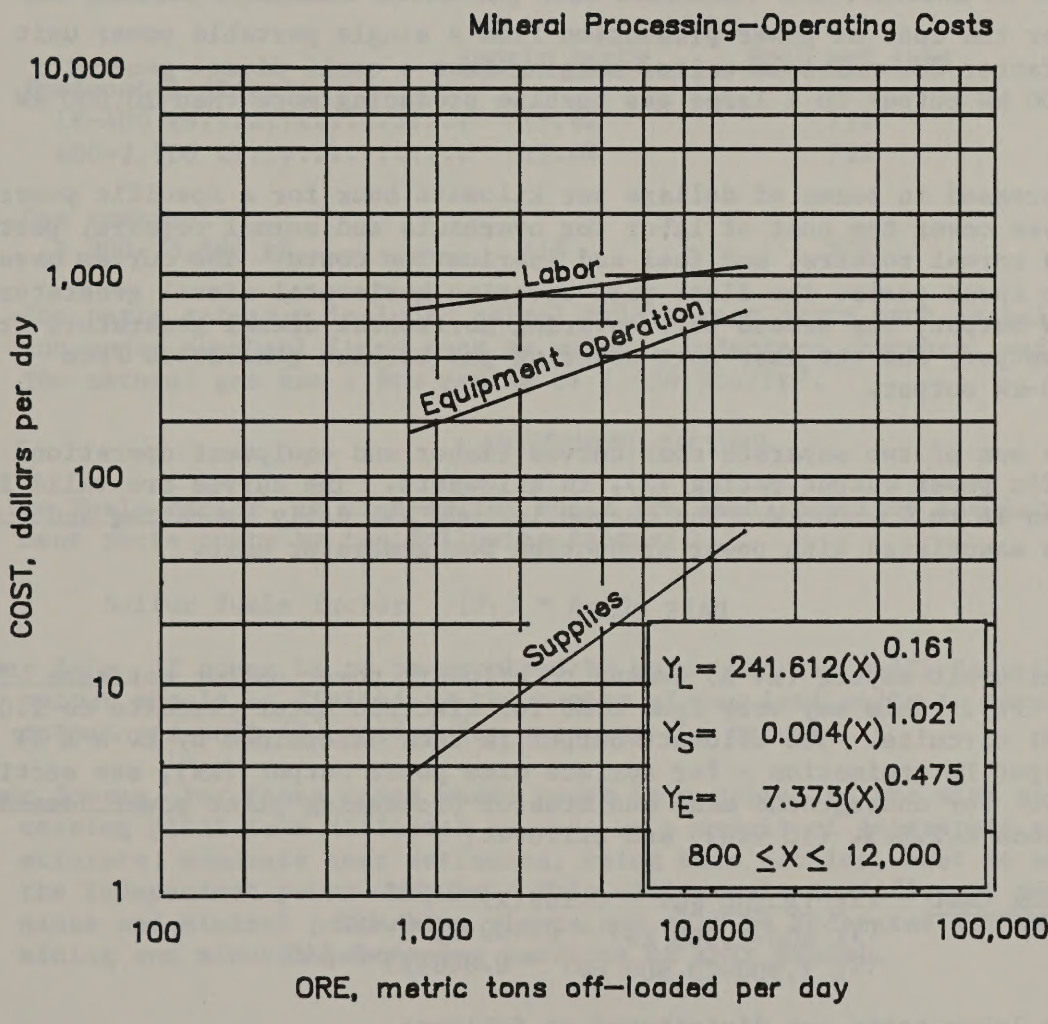
The average wage for labor is $15.38 per worker-hour (including burden and average shift differential).

(S) Supply Operating Costs $(Y_S) = 0.004(X)^{1.021}$
The supply curve consists of 100% electric power.

(E) Equipment Operating Costs $(Y_E) = 7.373(X)^{0.475}$
The equipment operating cost consists of 94% for repair and maintenance parts and 6% for lubrication.

ADJUSTMENT FACTOR

Variable Shift Rate If the offloading facility is to be operated one shift per day, multiply the daily off-loading rate by two; calculate the operating costs from the base curves using the adjusted rate, then decrease the calculated cost by 50% to arrive at the adjusted cost. If the facility is operating three shifts per day, multiply the daily off-loading rate by 0.67; calculate the operating costs from the base curves using the adjusted off-loading rate, then increase the calculated cost by 50% to arrive at the adjusted cost.



7.1.8.6.2. Loading facilities
OFF-LOADING FACILITIES

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.8. GENERAL OPERATIONS

7.1.8.11. PORTABLE POWER GENERATION

This section is to be used in conjunction with section 6.1.8.11. when electrical power is unavailable through a commercial power utility company or when it would be uneconomical to run power distribution facilities to the user. The total cost per kilowatt hour replaces the commercial Denver, CO, power rate used in other sections of this manual.

These curves cover the cost of power production from a single portable power unit (see adjustment factor for multiple units) ranging from a small diesel generator with less than 100 kW output to a large gas turbine producing more than 20,000 kW of power.

Total cost is expressed in terms of dollars per kilowatt hour for a specific power output. The curves cover the cost of labor for overhauls and normal repairs, parts for overhauls and normal repairs, and fuel and lubrication costs. The curves have been divided into three parts: the first part covering horizontal diesel generators from 18-to 400-kW output, the second part covering horizontal diesel generators from 400 to 2,900-kW output, and the last part covering gas turbine generators from 2,900-W to 23,600-kW output.

Total cost is the sum of two separate cost curves (labor and equipment operation) based on a specific power output rating (X), in kilowatts. The curves are valid for generators between 18 to 23,600 kW. The curves include all daily operating and maintenance costs associated with power production per generator unit.

BASE CURVE

To convert from kilovolt ampere (kV·A) demand to kilowatt power output estimate the power factor (PF). This may vary from 0.80 for electric motor circuits to 1.00 for electric light circuits. The kilowatt output is then determined by kV·A X PF = kW. [Power Output Determination - for surface mine power output (kW), see section 2.2.4.2 (IC 9142). For underground mine and mineral processing plant power demand (kV·A), see sections 4.2.5.3. (IC 9142) and 6.1.8.4.]

(L) <u>Labor Operating Cost</u> $(Y_L\ 18\text{-}400\ kW) = 0.169(X)^{-0.466}$
$(Y_L\ 400\text{-}2{,}900\ kW) = 0.409(X)^{-0.480}$
$(Y_L\ 2{,}900\text{-}23{,}600\ kW) = 0.008(X)^{-0.445}$

The operating labor costs are distributed as follows:

Direct labor................	0%
Maintenance labor...........	100%

The labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Mechanics...................	100%	$18.11

The average wage for labor is $18.11 per worker-hour (including burden and average shift differential).

The labor curves do not contain any operating labor costs since all units operate unattended in an automatic mode (some smaller units may not have automatic starting systems and would require a manual start). The only labor necessary is that which is required for maintenance and scheduled overhauls by mechanics.

(E) Equipment Operation Costs $(Y_E\ 18\text{-}400\ kW) = 0.145(X)^{-0.075}$
$(Y_E\ 400\text{-}2{,}900\ kW) = 0.158(X)^{-0.070}$
$(Y_E\ 2{,}900\text{-}23{,}600\ kW) = 0.131(X)^{-0.122}$

The general equipment operating cost component distribution is as follows:

	Repair parts	Fuel and lube	Tires
Horizontal diesel:			
18-400 kW..................	18.0%	73%	9%
400-2,900 kW..............	12.0%	79%	9%
Gas turbine:			
2,900-23,600 kW...........	11%	75%	14%

The parts category includes normal maintenance parts such as belts and pumps, and major overhaul items such as valves, injectors, brushes, and commutators. The natural gas has a Btu rating of 1,050 Btu/ft^3.

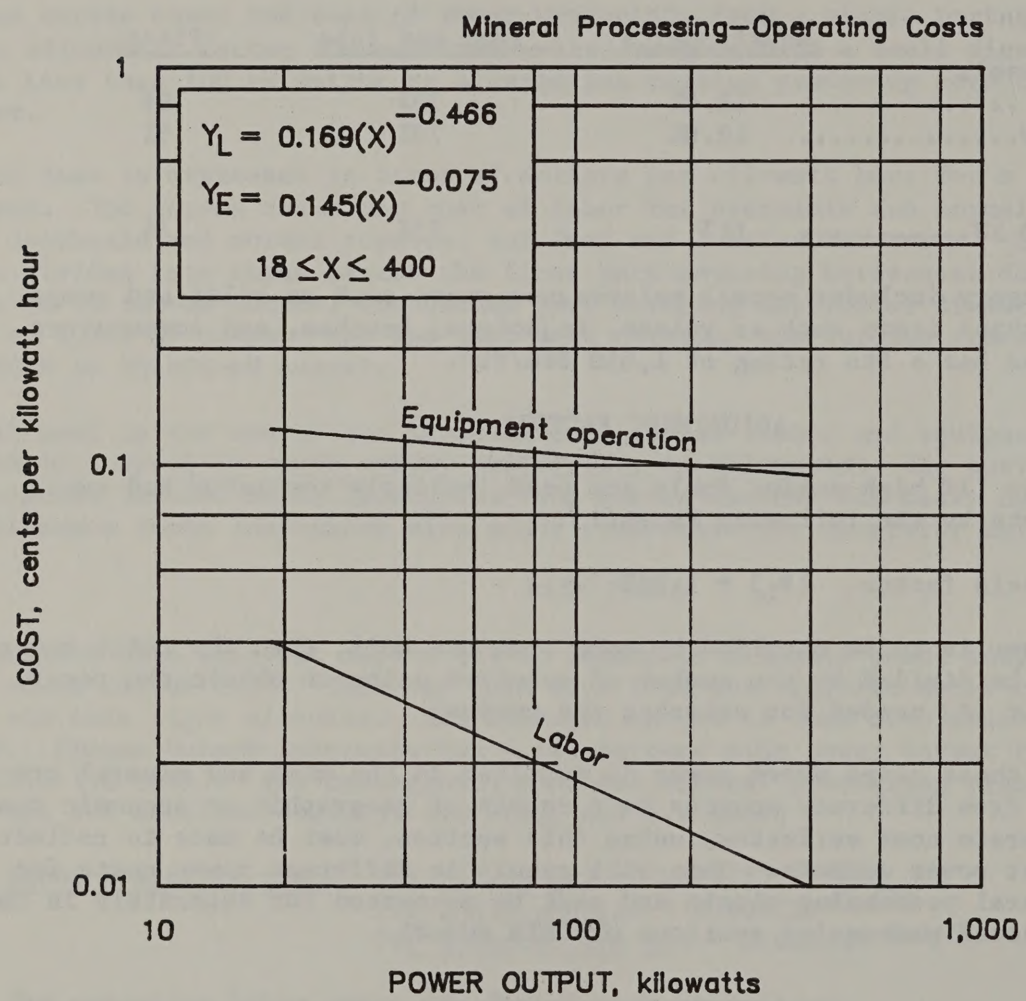
ADJUSTMENT FACTORS

Sulfur Fuels Factor If high-sulfur fuels are used, multiply the labor and equip ment parts costs by the following factor:

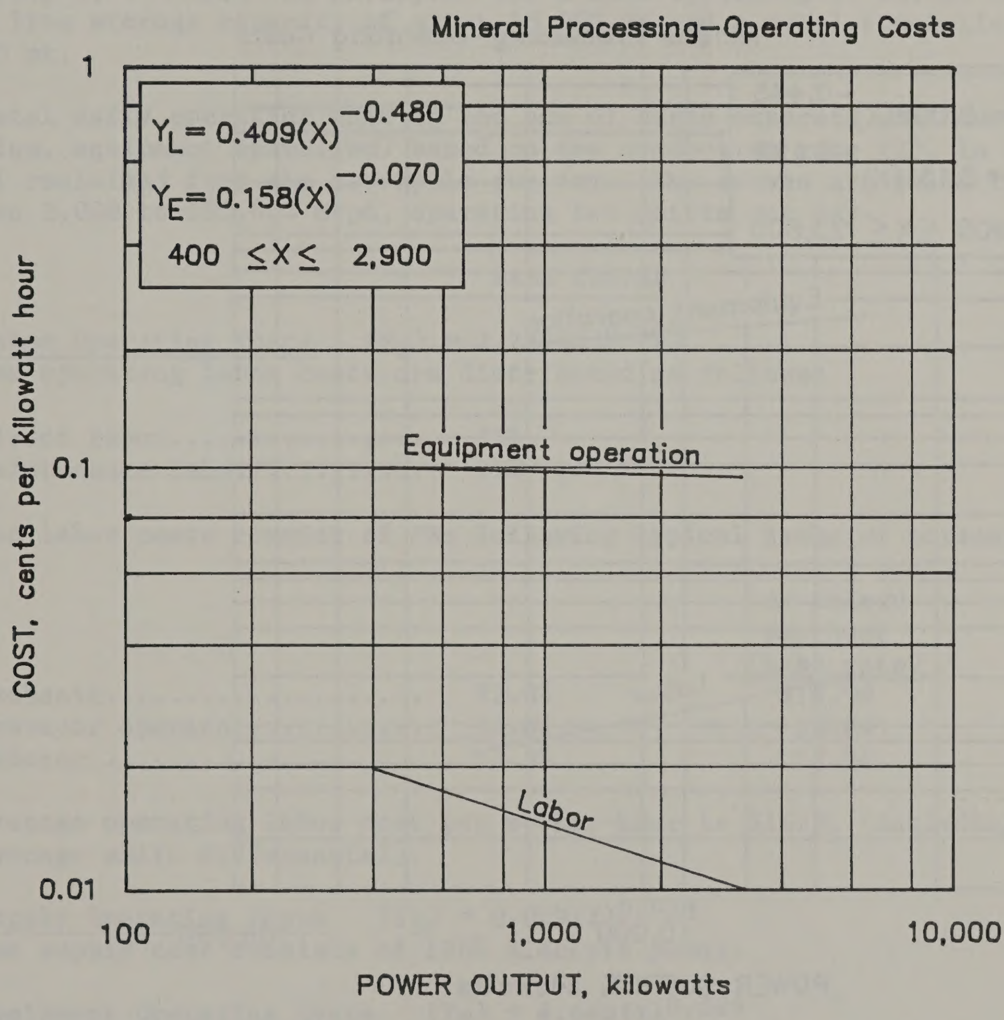
Sulfur fuels factor $(F_L) = 1.333$

Power Rate If power is to be supplied by more than one unit, then the total power output should be divided by the number of required units to obtain the power output per unit (X) needed for entering the curves.

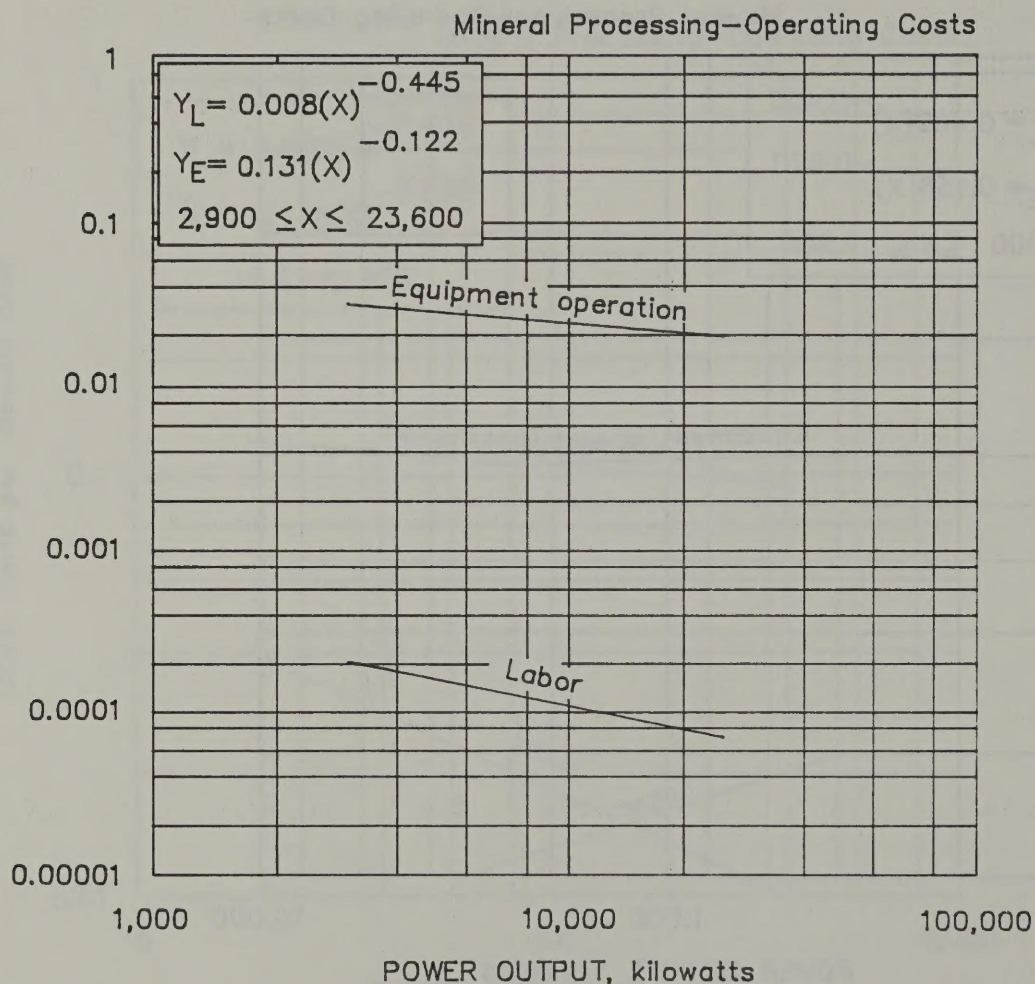
Power Source For those cases where power is supplied to the mine and mineral processing plant from different sources as a result of geographic or economic constraints, separate cost estimates, using this section, must be made to reflect the independent power outputs. This will result in different power costs for mines and mineral processing plants and must be accounted for separately in the mining and mineral processing sections of this manual.



7.1.8.11.a Portable power generation



7.1.8.11.b Portable power generation



7.1.8.11.c Portable power generation

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.8. GENERAL OPERATIONS

7.1.8.12. STOCKPILE STORAGE FACILITIES

Stockpile operating costs, as determined in this section, are based on metric tons of stockpiled material reclaimed during a two-shift-per-day operation. The costs represented are only applicable for stockpiles formed and reclaimed by conveyors. The daily reclaim rate is typically about 67% of the stockpile's live storage capacity. Total stockpile capacity is normally about 600% of the daily reclaim rate. For example, a coarse ore stockpile for a mill operating at 10,000 mt of ore per day has a live storage capacity of about 15,000 mt and a total stockpile capacity of 60,000 mt.

The total daily operating cost is the sum of three separate cost curves (labor, and supplies, equipment operation) based on the production rate (X), in metric tons material reclaimed from the stockpile per day. The curves are valid for operations between 2,000 to 200,000 mtpd, operating two shifts per day.

BASE CURVES

(L) Labor Operating Costs $(Y_L) = 7.229(X)^{0.503}$
The operating labor costs are distributed as follows:

Direct labor................	33%
Maintenance labor...........	67%

The labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Mechanic....................	72.0%	$17.99
Conveyor operator...........	14.8%	14.89
Laborer.....................	13.2%	13.26

Average operating labor cost per worker-hour is $16.91 (including burden and average shift differential).

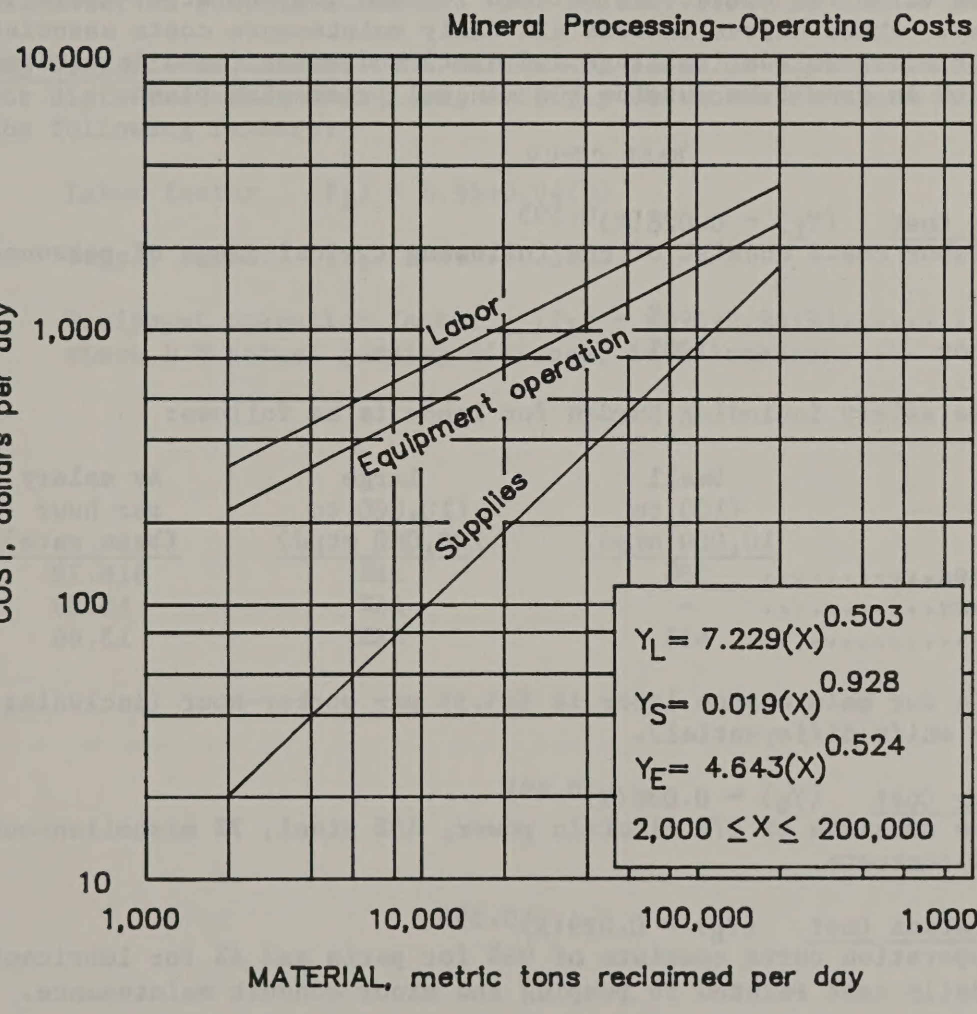
(S) Supply Operating Costs $(Y_S) = 0.019(X)^{0.928}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Costs $(Y_E) = 4.643(X)^{0.524}$
The equipment operating cost consists of 94% for repair and maintenance parts and 6% for lubrication.

ADJUSTMENT FACTOR

Shift-Reclaim Rate If a stockpile facility is operated one shift per day, multiply the daily reclaim rate by two; calculate the operating costs from the base curves using the adjusted reclaim rate; then decrease the calculated cost by 50% to arrive at the adjusted cost. If the facility is operated three shifts per

day, multiply the daily reclaim rate by 0.67; calculate the operating costs from the base curves using the adjusted reclaim rate; then increase the calculated cost by 50% to arrive at the adjusted cost.



7.1.8.12. Stockpile storage facilities

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.8. GENERAL OPERATIONS

7.1.8.14.1. WATER AND DRAINAGE SYSTEM DRAINAGE AND DISPOSAL SYSTEM

These curves cover the cost of general drainage control around the mineral processing area, including collection conduits, sumps and pumps, and pipelines or culverts.

The total operating cost is the sum of three cost curves (labor, supplies, and equipment operation) based on the capacity rate (X), in metric tons of mill feed per day. The curves are valid for operations between 100 and 100,000 mtpd, operating three shifts per day. These curves include all daily maintenance costs associated with the disposal of minor solids (spillage and dust) and water (used in equipment and floor washing) to an area 1 km outside the mineral processing plant.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 0.028(X)^{0.595}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	0%
Maintenance labor...........	100%

The average base salary including burden for labor is as follows:

	Small (100 to 10,000 mtpd)	Large (10,000 to 100,000 mtpd)	Av salary per hour (base rate)
Mechanic 2d class...........	55%	28%	$16.78
Mechanic 3d class...........	-	26%	15.89
Helper......................	45%	46%	13.66

The average wage for maintenance labor is $15.55 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.038(X)^{0.691}$
The supply curve consists of 47% electric power, 43% steel, 7% miscellaneous materials, and 3% concrete.

(E) Equipment Operation Cost $(Y_E) = 0.029(X)^{0.591}$
The equipment operation curve consists of 96% for parts and 4% for lubricants. It covers the daily cost related to pumping and minor conduit maintenance.

ADJUSTMENT FACTORS

The operating cost curves are based on disposing of a water quantity equal to one-third of the plant makeup water, containing an average solids equivalent of 0.25% of plant feed. The makeup water is considered here to be 25% of the total water required daily for mineral processing.

Pumping Head Adjustment The supply curve is based on an typical pumping head of 16.3 m, 15 m static head and 1.3 m friction head. If the actual drainage circuit involves gravity flow or an unusually high head (H), multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.040+0.059(H)$

Supply factor $(F_S) = 0.530+0.029(H)$

Equipment operation factor $(F_E) = 0.040+0.059(H)$
where H = actual head, in meters.

For approximate values of H, add to the static head (lift) 1 to 2 m for each kilometer of pumping distance. For gravity flow the static head is zero.

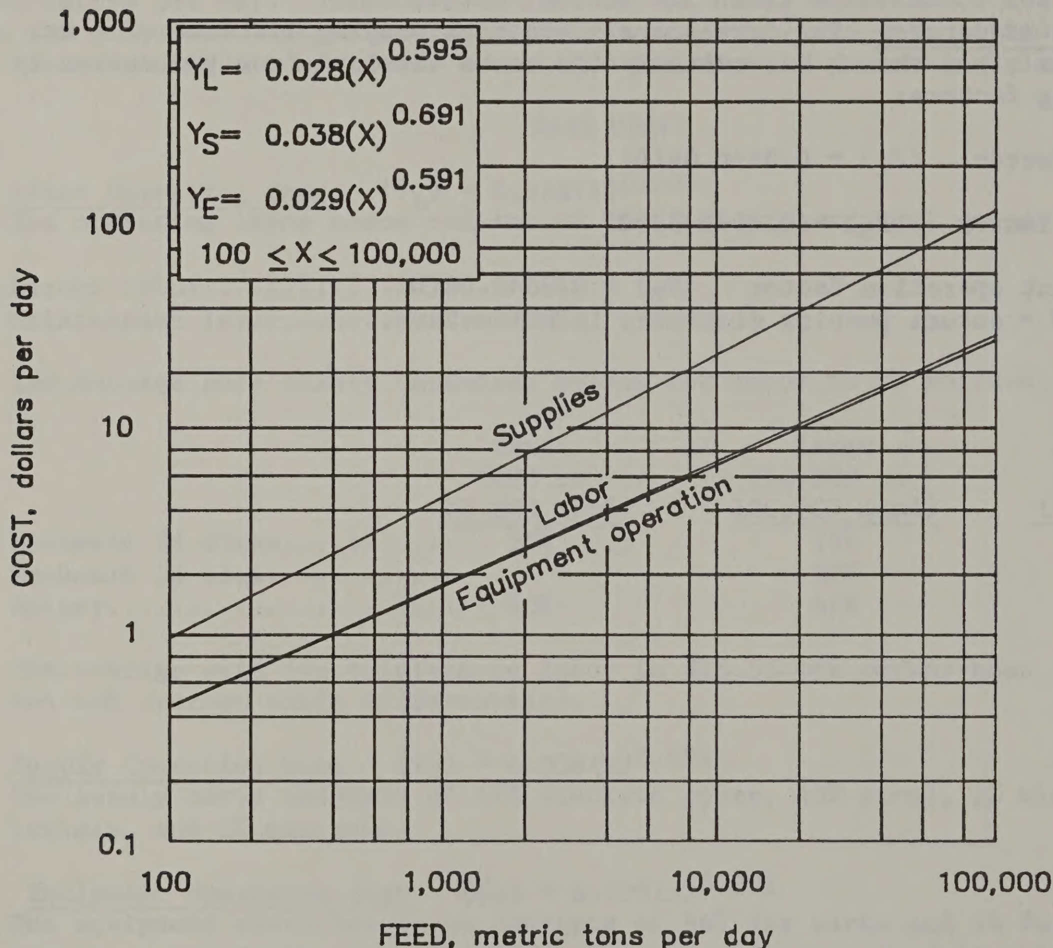
Pumping Distance Adjustment The curves are based on a pumping distance of 1 km. For distances other than 1 km, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.96+0.04(D)$

Supply factor $(F_S) = 0.47+0.53(D)$

Equipment operation factor $(F_E) = 0.96+0.04(D)$
where D = actual pumping distance, in kilometers.

Mineral Processing—Operating Costs



7.1.8.14.1. Water and drainage system
DRAINAGE AND DISPOSAL SYSTEM

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.8. GENERAL OPERATIONS

7.1.8.14.2. WATER AND DRAINAGE SYSTEM
WATER SUPPLY SYSTEM (MAKEUP WATER)

Water is used in mineral processing plants primarily for washing or concentration. Depending on the mineral processing method, the water volume required will vary. The water supply system operating cost for a processing plant [and/or an adjoining mine, section 3.2.4.10.2. (IC 9142)] is based on the daily water consumption.

The total daily operating cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on the makeup water volume (X), in cubic meters of water per day. The curves are valid for volumes between 1,000 and 150,000 m^3/d, operating one shift per day. The curves cover all daily maintenance and operating costs associated with water wells, storage tanks, pipelines and distribution. For mill water reclamation, see section 6.1.4.5.

For flotation plants, the total water required varies from 2.5 to 4.5 m^3/mt floated. Ten to forty percent of the water required is makeup water. Gravity concentration may require as much as 8 m^3 of water per metric ton of ore feed. About 10% of this figure is new water and the rest reclaimed.

If total daily volume (processing-plant makeup water and mine water) is known, the manual user should enter this volume in the equations given below (unless the mine is supplied with water from an independent source). The total operating cost may be allotted as follows:[1]

a. 91% to mineral processing (section 7.1.8.14.2.).

b. 9% to surface mine [section 3.2.4.10.2. (IC 9142)].

[1]Percentages derived from BuMines IC 8285 dealing with water consumption for U.S. mines and mineral processing plants. Different percentages may be obtained if an actual breakdown of mine and mineral processing plant is known.

BASE CURVE

These curves are valid for a total pumping head ranging from 260 to 330 m with an average of 291 m, and pumping distances ranging from 3 to 53 km.

(L) Labor Operating Cost $(Y_L) = 1.937(X)^{0.445}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	0%
Maintenance labor...........	100%

The average base salary including burden for labor is as follows:

	Small (1,000 to 13,000 m^3/d)	Large (13,100 to 150,000 m^3/d)	Av salary per hour (base rate)
Mechanic-welder.............	25%	14%	$16.33
Pipefitter.................	34%	39%	$22.80
Helper......................	41%	47%	$13.66

The average wage for maintenance labor is $16.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.045(X)^{0.997}$
The supply cost consists of 100% electric power. Power is required to overcome the static head (well depth and lift) and pipeline head losses.

(E) Equipment Operation $(Y_E) = 0.054(X)^{0.864}$
The equipment operation curve covers the daily operation cost for pipelines, pumps, and storage tanks. It consists of 95% for parts and 5% for lubricants.

ADJUSTMENT FACTORS

Pumping Distance Factor To correct for actual pumping distance, multiply the costs obtained from the curves by the following factor:

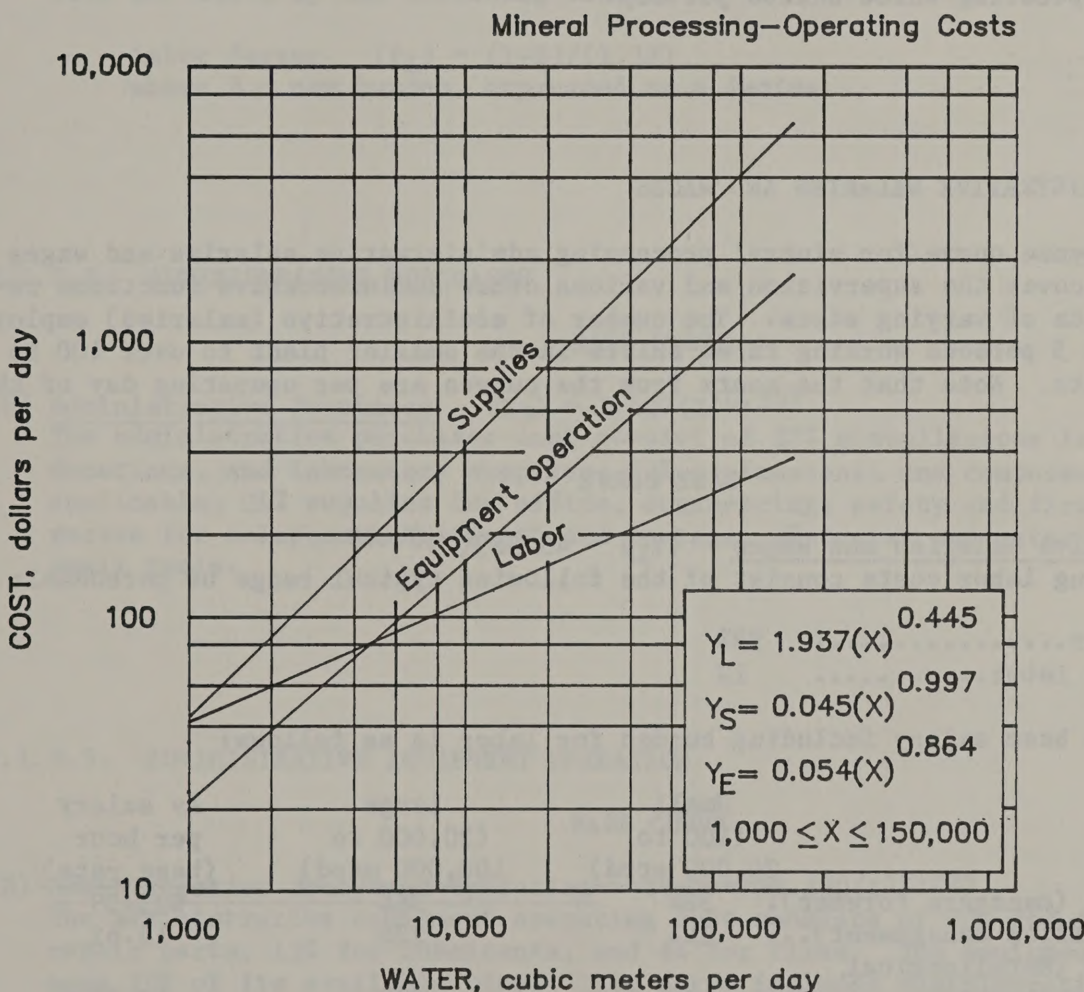
Pumping distance factor $(F_D) = 0.85+[1.95(D)(X)^{-0.549}]$
where D = actual distance, in kilometers,
and X = volume, in cubic meters per day.

Because a change in distance results in a change in friction head, also multiply the costs by the pumping head factor (F_H).

Pumping Head Factor The three cost curves are based on 244-m static head (well depth and lift) and a 47-m friction head. To adjust for actual total heads, multiply the costs obtained from the curves by the following factor:

Pumping head factor $(F_H) = H/291$
where H = sum of the actual static, friction, velocity, fitting, and discharge heads, in meters.

Purchased Water Factor If water is purchased, estimate the labor, supply, and equipment operation costs (from the delivery point to the mine and processing plant), and add them to the purchasing cost.



7.1.8.14.2. Water and drainage system
WATER SUPPLY SYSTEM (MAKEUP WATER)

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.9. GENERAL EXPENSES
ADMINISTRATIVE COSTS

These costs include expenses incurred in the everyday operation of the plant and do not include general company overhead.

The total daily operating costs are from three separate cost curves (labor, supplies, and equipment operation) based on the capacity rate (X), in metric tons of processing plant feed per day. The curves are valid for operations between 100 and 100,000 mtpd, operating three shifts per day.

7.1.9.1. ADMINISTRATIVE SALARIES AND WAGES

The general expense curve for mineral processing administrative salaries and wages is intended to cover the supervision and various other administrative functions required for plants of varying sizes. The number of administrative (salaried) employees varies from 5 persons working three shifts in the smaller plant to over 100 in the larger plants. Note that the costs from the curves are per operating day of the plant.

BASE CURVE

(L) Administrative Salaries and Wages $(Y_L) = 43.589(X)^{0.488}$
The operating labor costs consist of the following typical range of personnel:

Direct labor................	99%
Maintenance Labor...........	1%

The average base salary including burden for labor is as follows:

	Small (100 to 20,000 mtpd)	Large (20,000 to 100,000 mtpd)	Av salary per hour (base rate)
Supervision (managers foremen).	36%	36%	$23.39
Clerical (office management)...	21%	22%	13.62
Engineering (Metallurgical chemical, mechanic)...........	18%	20%	19.85
Assaying and metallurgical.....	12%	11%	15.13
Purchasing and warehousing.....	9%	7%	14.14
Safety, first aid, security....	4%	4%	18.85

The average wage for labor is $17.93 per worker-hour (including burden and average shift differential).

Selected median annual salaries are as follows (without burden):

Mill superintendent.........	$50,400
General maintenance foreman.	33,600
Chief electrician...........	40,900
Engineer....................	35,900
Safety director.............	35,900
Director of purchasing......	42,000

ADJUSTMENT FACTOR

Burden Factor If the burden is other than 32%, multiply the labor cost obtained from the curve by the following factor:

Labor factor $(F_L) = (1+B)/(1.32)$
where B = new burden, expressed as a decimal.

7.1.9.2. ADMINISTRATIVE PURCHASES

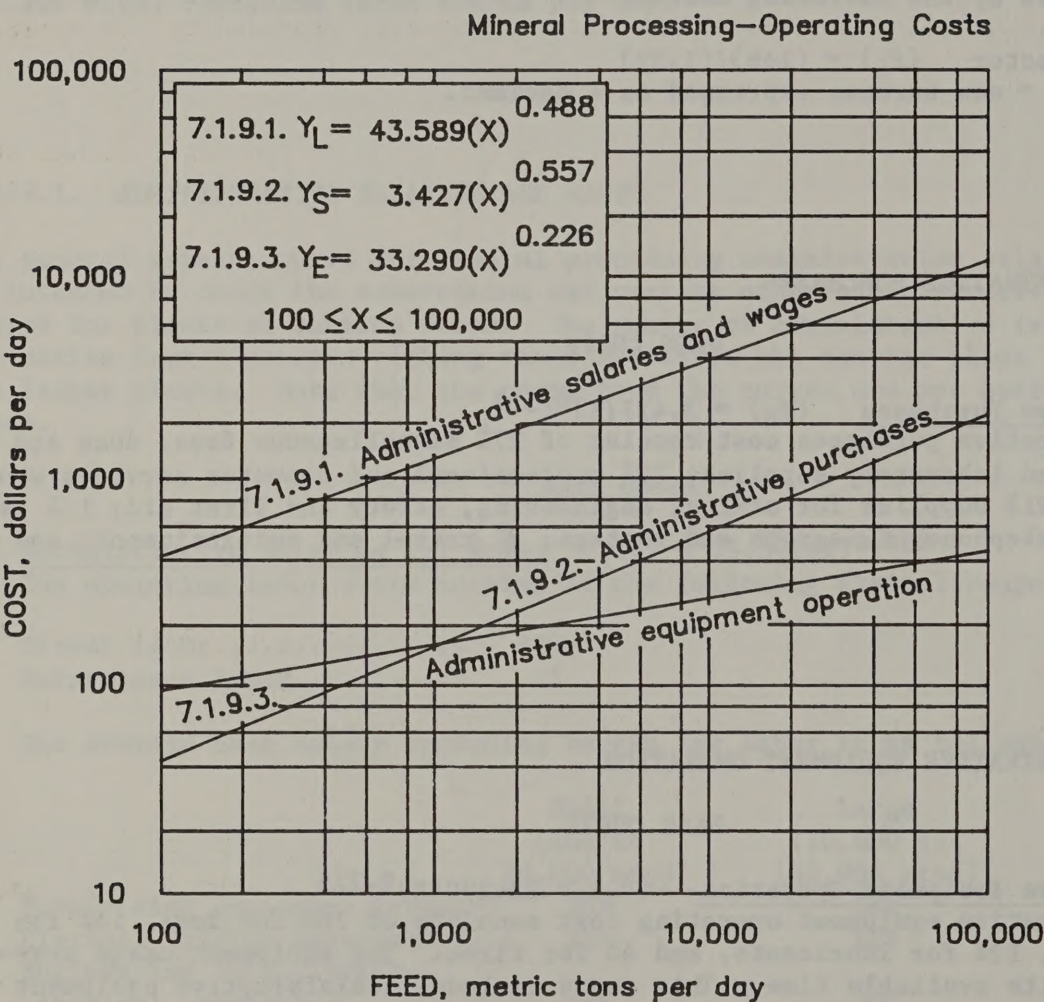
BASE CURVE

(S) Administrative Purchases $(Y_S) = 3.427(X)^{0.557}$
The administrative purchases cost consist of 27% miscellaneous fees, dues and donations, and laboratory supplies; 22% professional and computer services when applicable; 21% supplies for office, engineering, safety and first aid; 15% expenses for telephone, telegraph and postage; 9% travel and entertainment; and 6% small tools.

7.1.9.3. ADMINISTRATIVE EQUIPMENT OPERATION

BASE CURVE

(E) Administrative Equipment Operation $(Y_E) = 33.290(X)^{0.226}$
The administrative equipment operating cost consists of 70% for fuel, 14% for repair parts, 12% for lubricants, and 4% for tires. The equipment usage averages 20% of its available time. This curve includes administrative equipment operation expense for vehicles such as sedans, pickups, forklifts, and flatbed trucks.



7.1.9.1.—3. General expenses
ADMINISTRATIVE SALARIES AND WAGES
ADMINISTRATIVE PURCHASES
ADMINISTRATIVE EQUIPMENT OPERATION

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.10. INFRASTRUCTURE

7.1.10.2. TOWNSITE-CAMPSITE

CAMPSITE

Where conditions such as remote location or seasonal operation require a single-status campsite (i.e., room, board, and recreation facility), the daily operating cost should be derived from the following base cost curve. Today a caterer is usually employed to provide board, housekeeping, and recreation supervision. Heat, lights, garbage disposal, and plant maintenance are usually provided by the owner.

BASE CURVE

The total daily cost is derived from the supply curve based on the total number of persons who occupy the campsite (X). The curve is valid for campsites occupied by 20 to 1,000 persons. All persons receive both room and board.

(S) Supply Operating Cost $(Y_S) = 37.143(X)^{0.897}$

	Small (20 to 450 persons)	Large (450 to 1,000 persons)
Board......................	61.5%	59.0%
Housekeeping and recreation.	23.9%	23.0%
Heat.......................	6.4%	9.0%
Light......................	2.4%	3.4%
Maintenance................	5.8%	5.6%

If the number of persons requiring board varies from the number of persons requiring room, use the following equation:

(S) Supply Operating Cost $(Y_S) = [37.143(X)^{0.897}][0.60(B/R)+0.40(R)]$
where B = number of persons requiring board only,
and R = number of persons requiring room only.

These curves are based on a caterer who provides all necessary personnel for food service, housekeeping, distribution and collection of mail, monitoring recreation, etc., and all necessary supplies, such as pots, pans, dishes, silverware, sheets, pillowcases, blankets, waste cans, recreation supplies, janitorial supplies, food, etc. The evaluator must add the cost for local, State, or Federal taxes where required.

ADJUSTMENT FACTORS

Owner-Operator Factor When the facility is owner-operated rather than catered, multiply the cost obtained from the curve by the following factor:

Owner-operator factor $(F_O) = 0.93$

<u>Diesel Power Factor</u> When the electric power is provided by a diesel-electric system rather than a power line grid, multiply the cost obtained from the curve by the following factor:

Diesel power factor $(F_D) = 1.04$

TRAILER COURT

Where conditions such as remote location or lack of available housing require installation of a family trailer court complete with utilities, laundromat, recreation facilities, blacktop driveway, and possibly swimming pool, the daily operating cost should be derived from the following two curves. The total daily cost is derived from the supply curve, based on the total number of trailer spaces (X) required. The curve is valid for trailer courts with 20 to 1,000 units.

BASE CURVE

The curves are based on trailer and facility maintenance, insurance, casualty insurance, supervisory and worker wages, plus overhead, heat, and lights.

(S) <u>Supply Operating Cost</u> $(Y_{S\ FREE}) = 49.514(X)^{0.590}$
Company-owned mobile homes, spaces, and facilities where the trailers and spaces are free to supervisors and workers. The company pays all operating costs on the facility.

(S) <u>Supply Operating Cost</u> $(Y_{S\ RENTED}) = 1,676.049(X)^{-0.716}$
Company-owned mobile homes, spaces, and facilities where the trailers and spaces are rented to supervisors and workers. The company pays for any loss on the facility.

ADJUSTMENT FACTORS

<u>Swimming Pool Factor</u> When the trailer court does not provide a swimming pool, multiply the curve $(Y_{S\ FREE})$ by the following factor:

Swimming pool factor $(F_{P\ FREE}) = 0.82$

When the spaces and trailers are rented and the trailer court has 52 or more units, it will show a profit. If there are less than 52 units multiply the curve $(Y_{S\ RENTED})$ by the following factor:

Swimming pool factor $(F_{P\ RENTED}) = 0.05$

<u>Trailer Space Rental Factor</u> When the occupants rent trailer space for their own trailers, multiply the curve $(Y_{S\ FREE})$ by the following factor:

Trailer space rental factor $(F_{R\ FREE}) = 0.36$

PERMANENT HOUSING

Company totally owned and operated townsites are decreasing in number because of their high cost and persistent social problems. The trend seem to be toward small family housing facilities combined with an existing nearby city.

Large townsite permanent housing

Today, the military appears to be the greatest user of this type of facility. The Air Force provides housing to its officers and enlisted personnel. The Government pays for housing and facility maintenance, all utilities, supervisor, and worker labor, etc. The average operating costs for 1983 were:

McCord Air Base--993 units: \$6.66 per day per unit
Fairchild Air Base--1,580 units: \$6.93 per day per unit

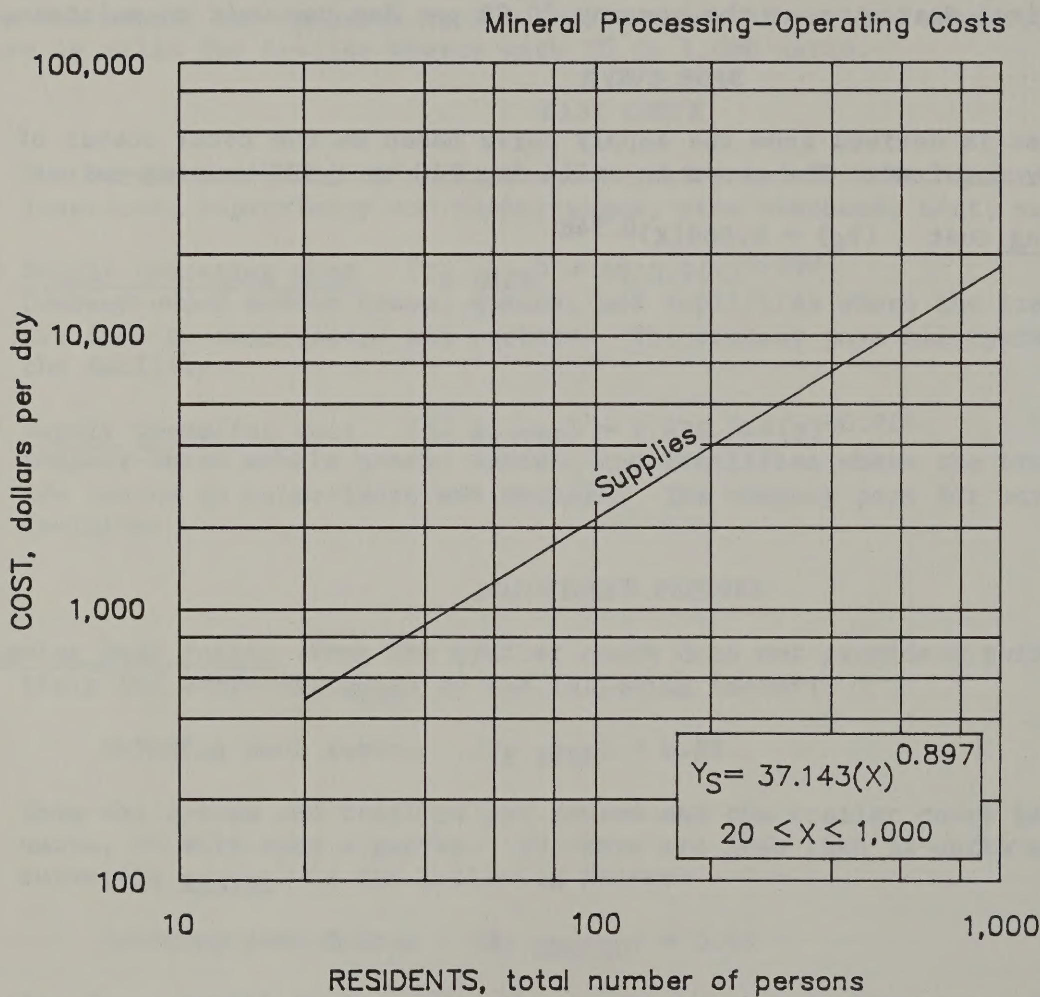
Small townsite permanent housing

These facilities are generally rented to their occupants at a modest fee, with the company paying for the general maintenance, insurance, and taxes. Rent is applied to the capital investment. A new housing facility (175 family units) in the western United States, cost the company \$0.98 per day per unit to maintain.

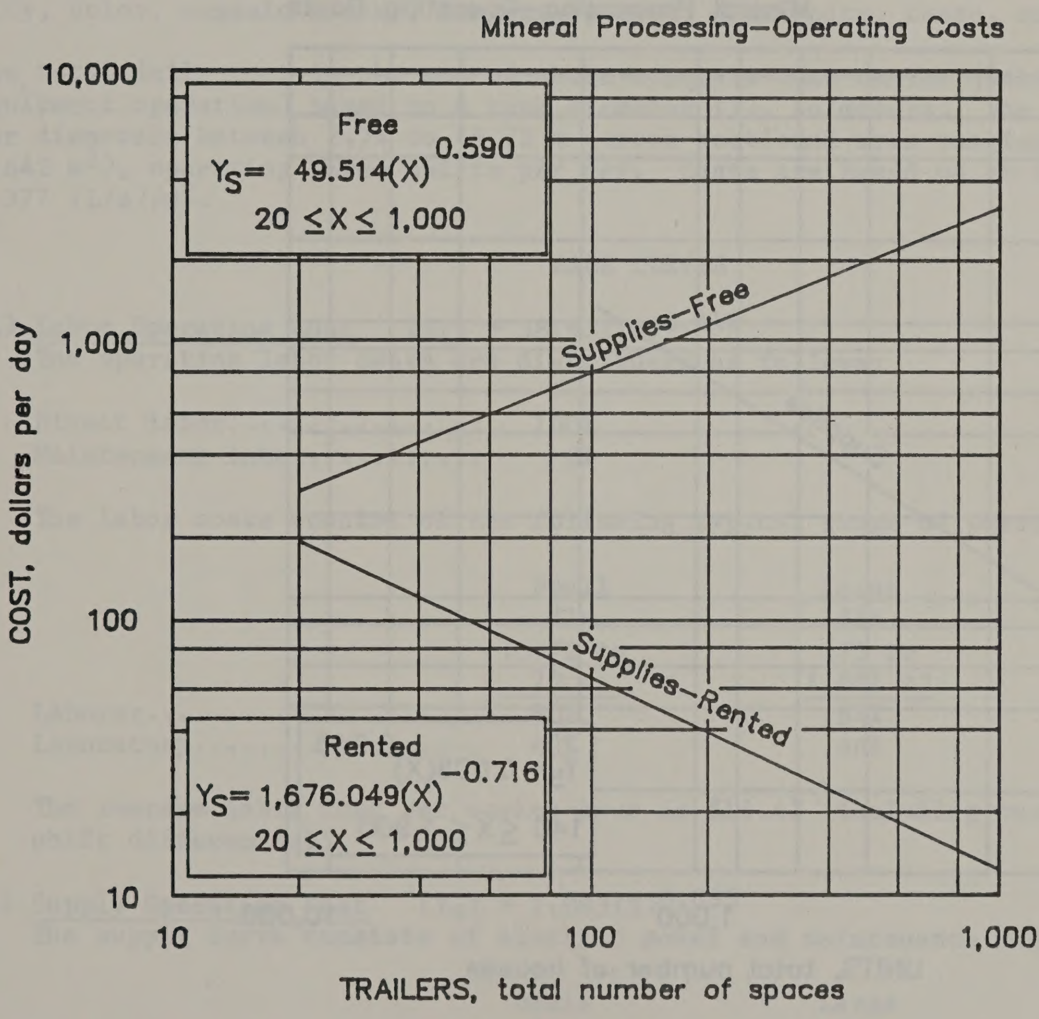
BASE CURVE

The total daily cost is derived from the supply curve based on the total number of housing units, (X), required. The curve is valid for 140 to 1,900 housing units.

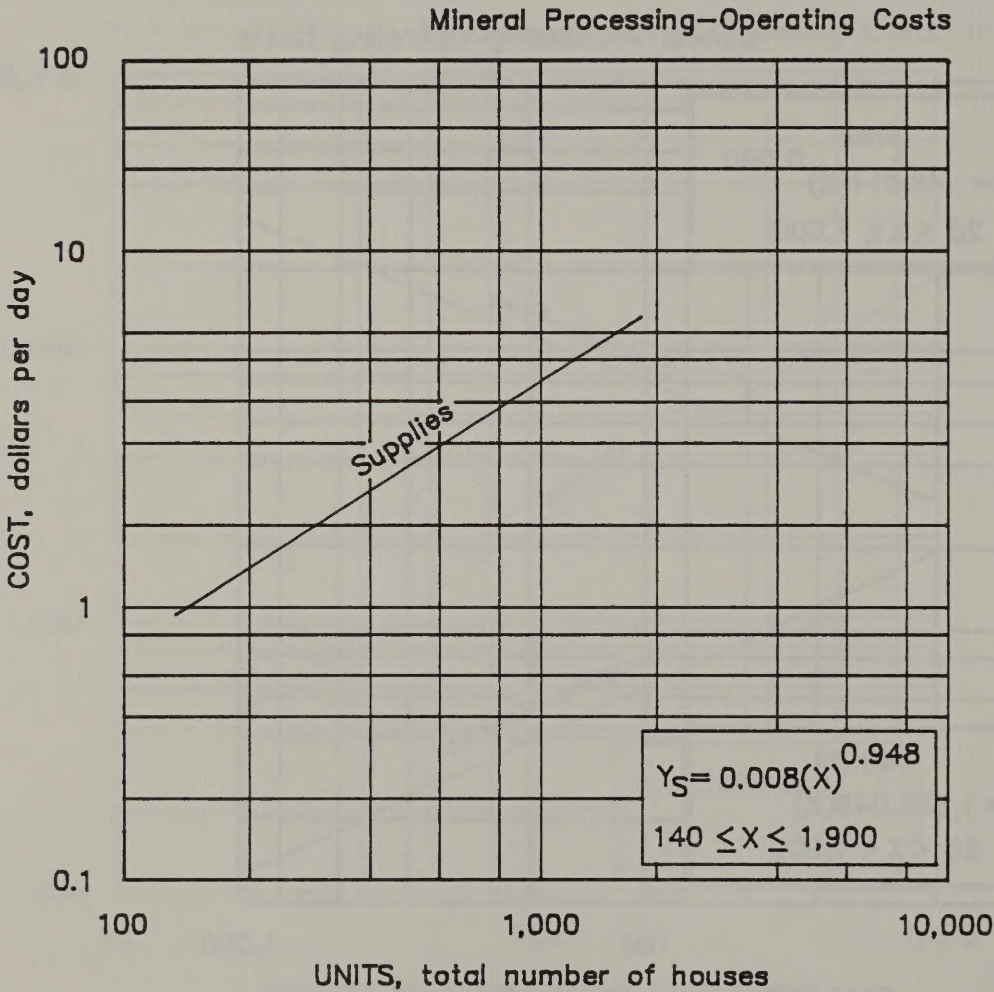
(S) <u>Supply Operating Cost</u> $(Y_S) = 0.008(X)^{0.948}$



7.1.10.2.a Townsite-Campsite
CAMPSITE



7.1.10.2.b Townsite-Campsite
TRAILER COURT



7.1.10.2.c Townsite-Campsite
PERMANENT HOUSING

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.10. INFRASTRUCTURE

7.1.10.3.1. WASTE WATER TREATMENT CLARIFICATION

This operation is a solids-contact clarifier used for water clarification by precipitation and/or coagulation. This cost curve is intended to remove suspended solids formed after final neutralization of out-of-pipe effluent. The curves include all principal costs associated with the operation of the unit. It does not include costs for sludge removal. The unit can selectively or simultaneously remove turbidity, color, organic matter, manganese, iron, alkalinity, taste, and odor.

The total daily cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a tank diameter (X), in meters. The curves are valid for diameters between 2.74 to 45.72 m (cross-sectional area ranging from 5.9 to 1,642 m^2), operating three shifts per day. Costs are based on an overflow rate of 0.377 $(L/s)/m^2$.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 38.931(X)^{0.119}$
The operating labor costs are distributed as follows:

Direct labor................	100%
Maintenance labor...........	0%

The labor costs consist of the following typical range of personnel:

	Small dia (5.72 to 75 m	Large dia (75 to 1,661 m)	Av salary per hour (base rate)
Laborer.....................	60%	54%	$13.66
Laboratory..................	40%	46%	15.89

The average labor cost per worker-hour is $14.43 (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.083(X)^{0.633}$
The supply curve consists of electric power and maintenance supplies.

	Small dia (5.72 to 75 m)	Large dia (75 to 1,661 m)
Electric....................	60%	34%
Maintenance.................	40%	66%

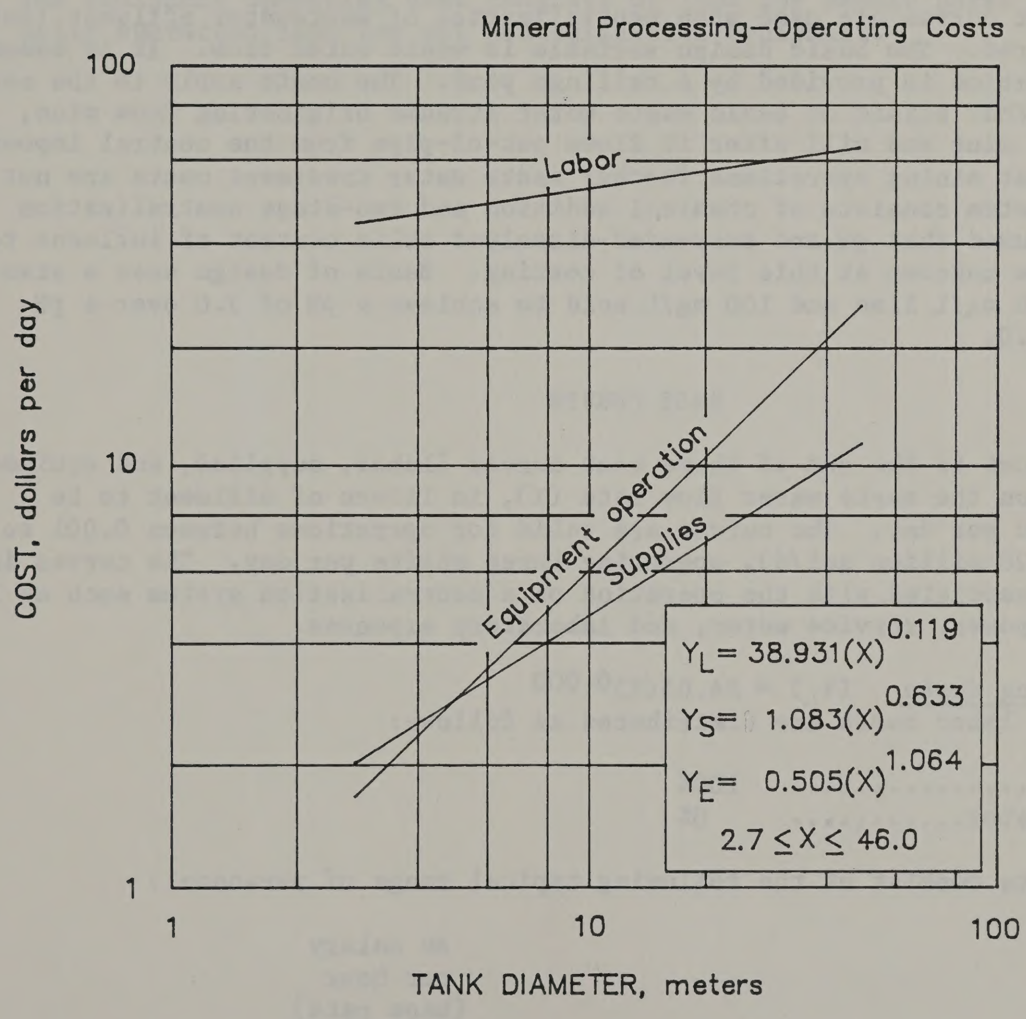
(E) Equipment Operating Cost $(Y_E) = 0.505(X)^{1.064}$
The equipment operating cost consists of 100% for repair parts and covers the daily operation cost for all clarification equipment.

ADJUSTMENT FACTOR

<u>Flocculant Factor</u> Normally, additional flocculants are not needed in the mine waste water treatment after neutralization. However, if polymers are needed or used, add the following factor to the supply cost obtained from the curve:

Supply factor $(F_S) = 0.334(D)^{1.812}$
where D = clarifier tank diameter, in meters.

The polymer is based on a standard dosage of 1.5 mg/L influent and an average polymer cost of $2.10/lb.



7.1.10.3.1. Wastewater treatment
CLARIFICATION

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.10. INFRASTRUCTURE

7.1.10.3.2. WASTE WATER TREATMENT
NEUTRALIZATION

The Environmental Protection Agency's publication EPA-600/2-82-00/d "Treatability Manual, Vol. IV, Cost Estimating," April 1983, was the source of cost development. One is referred to this manual if further detail in neutralization costs is needed. Additionally, other waste water treatment methods are costed in this EPA manual.

The operating cost curves are used when neutralization of wastewater effluent (out-of-pipe) is required. The basic design variable is waste water flow. It is assumed that flow equalization is provided by a tailings pond. The costs apply to the neutralization of either acidic or basic waste water streams originating from mine, mill, or combined mine and mill after it flows out-of-pipe from the central impoundment pond. In most mining operations further waste water treatment costs are not required. The system consists of chemical addition and two-stage neutralization tanks. It is assumed that pH and suspended-dissolved solid content of influent to the system will be unknown at this level of costing. Basis of design uses a standard dosage of 100 mg/L lime and 100 mg/L acid to achieve a pH of 7.0 over a pH range of 6.5 to 8.0.

BASE CURVES

The total daily cost is the sum of three cost curves (labor, supplies, and equipment operation) based on the waste water flow rate (X), in liters of effluent to be treated per second per day. The curves are valid for operations between 0.001 to 876 L/s (22.8 to 20 million gal/d), operating three shifts per day. The curves include all costs associated with the operation of a neutralization system such as labor, lime, acid, power, service water, and laboratory expenses.

(L) Labor Operating Costs $(Y_L) = 84.85(X)^{0.000}$
The operating labor costs are distributed as follows:

Direct labor................	100%
Maintenance labor...........	0%

The labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Laborer.....................	89%	$15.80
Laboratory..................	11%	15.80

The average labor cost per worker-hour is $15.80 (including burden and average shift differential).

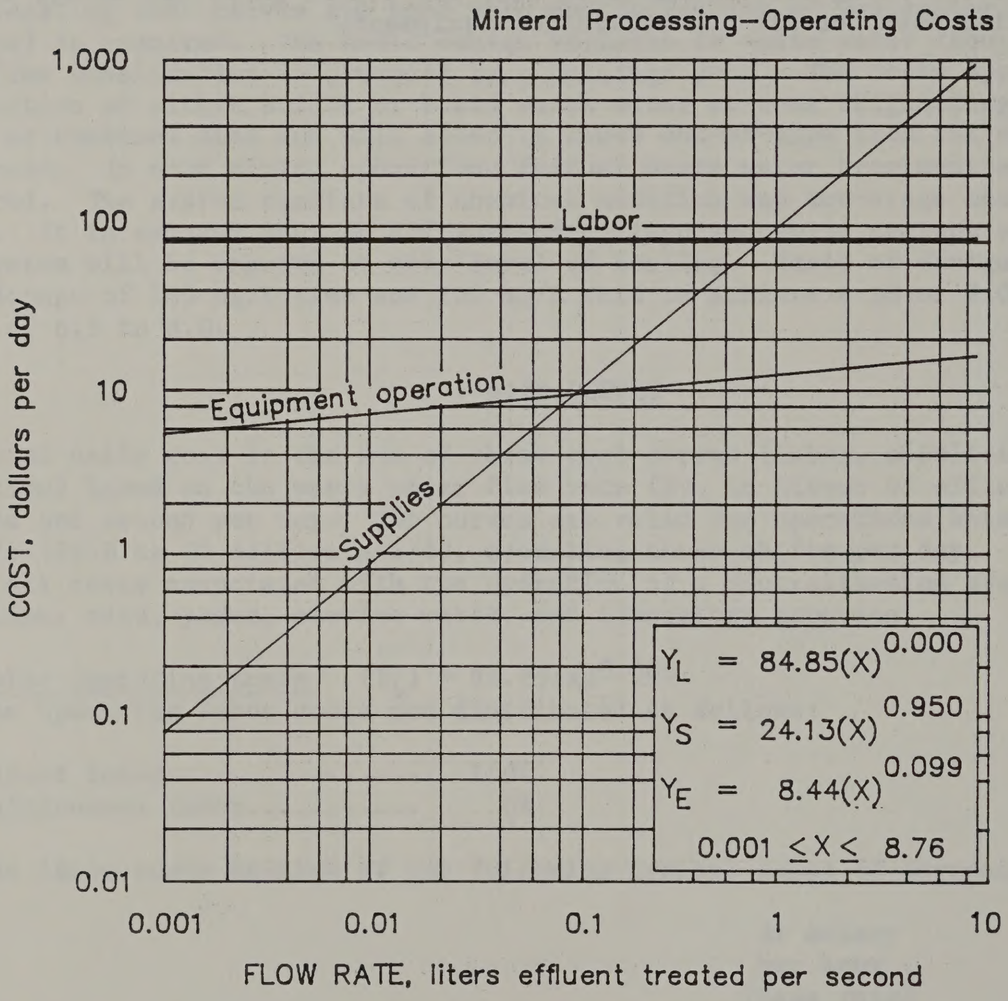
(S) Supply Operating Costs $(Y_{S\ 0.001\text{-}8.76\ L/s}) = 24.13(X)^{0.950}$
$(Y_{S\ 8.76\text{-}876\ L/s}) = 21.282(X)^{0.997}$

The supply costs consists of electric power, water, and chemicals and lime in the following proportions:

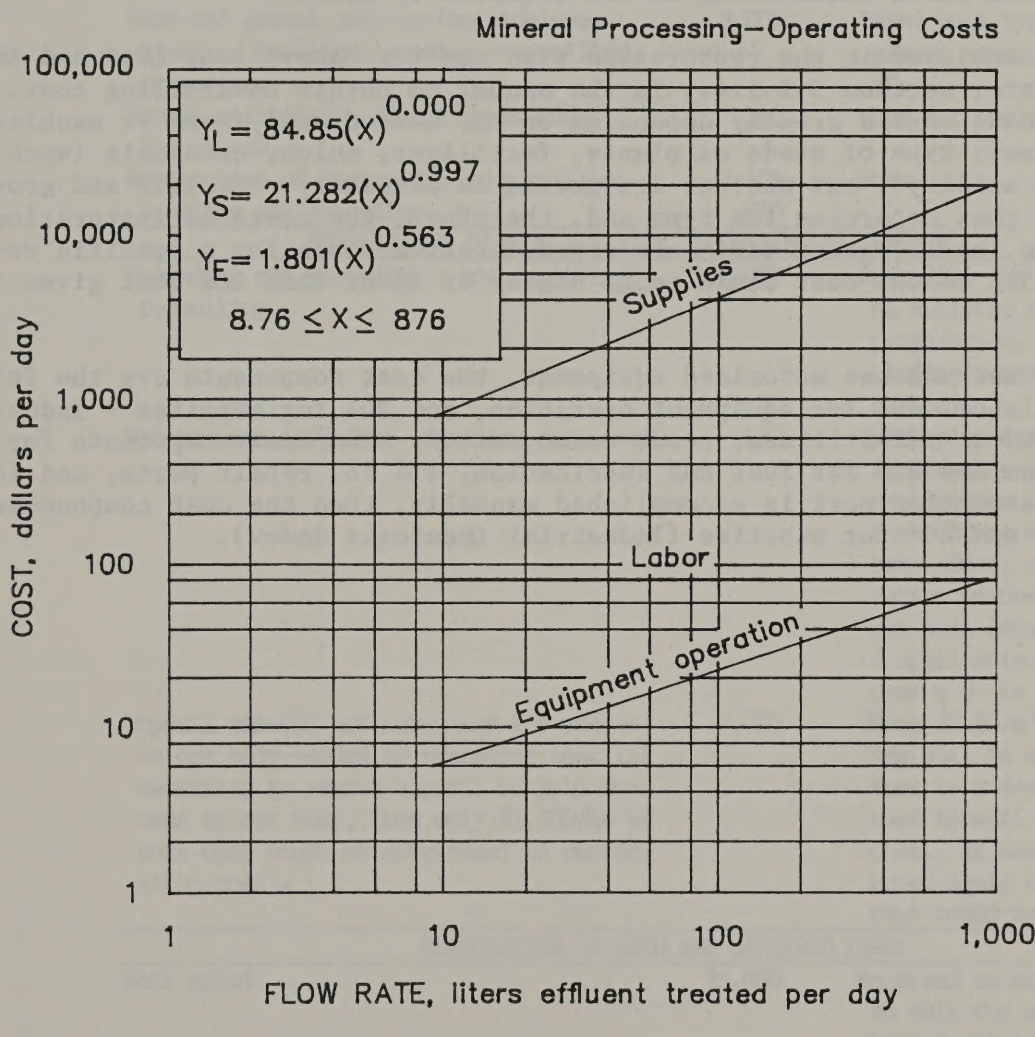
	Small (0.001 to 8.76 L/s)	Large (8.76 to 876 L/s)
Electric power..............	3%	2%
Water.......................	80%	89%
Chemicals and lime..........	17%	9%

(E) Equipment Operating Costs $(Y_E\ 0.001\text{–}8.76\ L/s) = 8.44(X)^{0.099}$
$(Y_E\ 8.76\text{–}876\ L/s) = 1.801(X)^{0.563}$

The equipment operating cost consists of 100% for repair parts and covers the daily operation cost for all neutralization equipment.



7.1.10.3.2.a Wastewater treatment
NEUTRALIZATION



7.1.10.3.2.b. Wastewater treatment
NEUTRALIZATION

7.1. MINERAL PROCESSING--OPERATING COSTS

7.1.11. RESTORATION DURING PRODUCTION

Mine restoration is the process of initiating and accelerating the natural continuous trend toward recovery (stabilization) etc.), the type of environment (desert, flatland, grass lands, mountains, etc.) and the restoration requirements by law in any given state (which range from none to very strict). Some states require permits prior to disturbing the ground surface. Typically, the permit specifies that the area must be reclaimed, hectare for hectare, to a use similar to the prior use or other beneficial use. Most restoration activities for mines include regrading and leveling plant sites (and revegetation of the disturbed area) but do not include backfilling (in most cases backfilling is not required by law).

If backfilling is employed in the restoration plan use the Excavation, Load and Haul Overburden and Waste, section 3.2.1.4., in the manual to obtain backfilling cost. The revegetation cost varies greatly depending on the method used (hand or machinery), materials used, type of seeds or plants, fertilizer, mulch, chemicals (such as lime for reducing acidity), and whether irrigation is necessary. Climate and ground slope are factors that determine the type and, therefore, the costs of restoration. The costs given in the following table are representative costs for a specific restoration task. The actual cost could range higher or lower than the cost given in the table.

Where restoration methods use motorized equipment, the cost components are the following: 40% for labor, 40% for equipment operation, and 20% for supplies - Industrial Chemicals Index - (fertilizer, seed, mulch, etc.). The cost components for equipment operation are 65% for fuel and lubrication, 25% for repair parts, and 10% for tires. If restoration work is accomplished manually, then the cost components are 60% for labor and 40% for supplies (Industrial Chemicals Index).

COST COMPARISONS OF RESTORATION METHODS

	Cost per hectare	Remarks
SPECIFIC RESTORATION WORK (INDEPENDENT OF CLIMATE OR GEOGRAPHY)		
Revegetation on steep slope—roadside slopes, tailing slopes, or waste dump slopes, using hydroseeder with fiber mulch.	$1,000-1,500	Based on using 18 kg/ha of seed, 73 kg/ha of fertilizer, and expenses to use a boom crane, pickup truck, 2 equipment operators, and a swamper.
Transplanting trees or shrubs by hand on moderate to steep slopes.	5,000	Assume 2,500 trees hand planted per hectare at $2 per tree or shrub.
Sand and gravel restoration, includes placers; leveling, grading, topsoiling, reseeding.	3,000	Based on a typical sand-and-gravel operation near Denver, CO.
Annual maintenance (fertilizers added for above).	160	Cost for applying fertilizer.
Restoration of borrow pit - backfilling leveling and reseeding.	400-600	None.
RESTORATION IN HIGH ALTITUDE (MOUNTAINOUS) TERRAIN		
Regrading and reseeding - not including topsoiling.	$4,000	Regrading for adequate drainage to minimize erosion, seedbed preparation, and reseeding (including transplanting trees and shrubs).
Maintenance (added to regrading cost cost).	130	Purchasing-applying fertilizer—application cost for 1 yr. If application is on area where at least 30-cm depth of topsoil has been added, only 1 year's application needed. If topsoil has not been added, then as many as 4 applications may be required over a 6- to 8-year period.
Topsoil removal not necessary for access to ore body—added to regrading cost (if necessary to remove topsoil to gain access to ore body, then only $1,300/ha of this cost would be attributed to restoration cost).	7,000	Using $2.30/m^3 cost of stockpiling soil to cover a disturbed area to a depth of 30 cm. Assume topsoil moved and emplaced once. If moved, then stored and moved again to final placement, cost could double).
RESTORATION IN ARID AND SEMIARID LANDS		
Soil added	$5,000	Required to achieve restoration on only the most severely disturbed sites. Generally serves to accelerate the rate of achieving permanent self-sustaining vegetation.

COST COMPARISONS OF RESTORATION METHODS—Continued

	Cost per hectare	Remarks
RESTORATION IN ARID AND SEMIARID LANDS—Continued		
Seeding and irrigation in arid climate on tailings dams, waste dump sites, road slopes.	$12,000-15,000	Irrigation system cost (sprinkler or drip tube) is estimated at $8,000/ha. Water assumed to be pumped on site at annual rate of 12,000 to 18,000 m^3/ha at $63 to $67 per 1,000 m^3 of water.
Seed and fertilizer broadcast on surface —no soil coverage or mulch.	700	Minimum slope where seed will cover naturally with soil. Seed broadcast manually.
Hydromulching with 680 kg wood fiber per hectare plus seed and fertilizer.	1,900-2,500	Most common southwestern U.S. hydromulch mix; will hold seed and fertilizer in place on steep and smooth slopes.
Straw or hay broadcast with straw blower on surface at 3,400 kg/ha.	2,500	Very effective as energy absorber and mulch. Not used on steep slopes. Cost increase significant if slopes over 14 m from access.

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.1. ACCESS ROADS

8.1.1.1. CLEARING

The total cost per kilometer is the sum of two separate cost curves (labor and equipment operation) having a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with clearing for access roads. Supplies have not been considered in the clearing costs because it is assumed that cleared brush or timber would be buried under the excavation waste; thus, supplies of fuel oil for burning the clearing slash are not required.

BASE CURVE

The curves are based on estimated costs for clearing medium growth on terrain with a side slope of 25%. Medium growth varies from heavy brush to one tree, 0.33 m in diameter, per 40 m^2.

(L) <u>Labor Operating Cost</u> $(Y_L) = 1{,}135.467(X)^{0.711}$

The operating labor costs are distributed as follows:

Direct labor...............	86%
Maintenance labor..........	14%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dozer operator.............	12%	$16.33
Wheel-loader operator......	12%	16.33
Flatbed-truck driver.......	12%	15.89
General laborer............	64%	13.86

The average wage for labor is $14.63 per worker-hour (including burden and average shift differential).

(E) <u>Equipment Operating Cost</u> $(Y_E) = 467.945(X)^{0.711}$

The equipment operating cost consists of 35% for repair parts, 53% for fuel and lubrication, and 12% for tires.

The equipment operating cost consists of

Dozer crawler..............	31%
Wheel loader...............	47%
Flatbed truck..............	12%
Pickup truck...............	9%
Chainsaws..................	1%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Dozer crawler.............	52%	48%	-
Wheel loader...............	36%	43%	21%
Flatbed truck..............	9%	80%	11%
Pickup truck...............	8%	90%	2%
Chainsaws..................	39%	61%	-

ADJUSTMENT FACTORS

Brush Factor For light clearing conditions where the growth consists mainly of brush and small trees, multiply the curves by the following factors:

Brush factor $(F_{B\ LIGHT}) = 0.25$

For heavy clearing conditions, defined as when clearing a dense growth of trees (diameter of the trees commonly exceeding 0.33 m), multiply the curves by the following factor:

Brush factor $(F_{B\ DENSE}) = 1.75$

Side Slope Factor For clearing on terrain with side slopes other than 20% to 30% multiply the curves by the following factors:

For clearing on terrain with side slopes of 0% to 20%,

Side slope factor $(F_{S\ 0\%-20\%}) = 0.8$

For clearing on terrain with side slopes of 30% to 50%,

Side slope factor $(F_{S\ 30\%-50\%}) = 1.8$

For clearing on terrain with side slopes of 50% to 100%,

Side slope factor $(F_{S\ 50\%-100\%}) = 2.5$

Burning Equation If fuel oil (for burning slash) or other supplies, such as cables and chokers, are used, add the following supply cost equation to the total cost per kilometer. The total cost per kilometer for supplies is for a roadway of width (X), in meters, varying in width from 3 to 30 m.

(S) Supply Operating Cost $(Y_{S\ BURNING}) = 269.796[0.100(X)]^{-0.0303}$

This cost is multiplied by the total kilometers, valid for values between 3.33 to 3,333.33 km, to obtain the capital cost.

For clearing operations from 1 to 500 ha (roadway width in meters multiplied by roadway length in meters multiplied by 0.0001), the supplies consist of 78% for fuel oil and 22% for tools, cables, and chokers. For clearing operations of 500 to 1,000 ha, supplies consist of 83% for fuel oil (for burning wood and scrub) and 17% for tools, cables, and chokers.

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation value by the following applicable factor in order to obtain the total value of equipment ex- pense for ownership and operation:

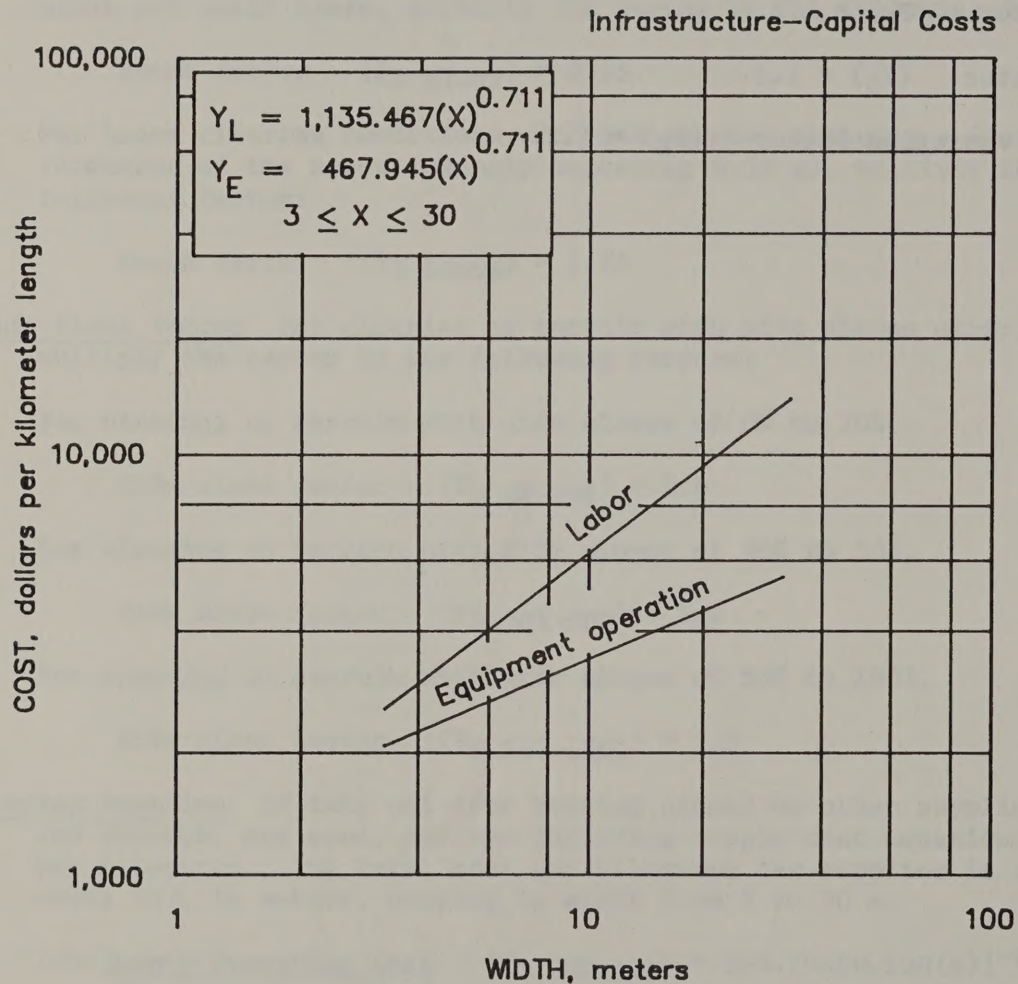
Shifts per day.............	1	2	3
Factor.....................	1.91	1.68	1.61

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curve by the following factors:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



8.1.1.1. Access road
CLEARING

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.1. ACCESS ROADS

8.1.1.2. DRILL AND BLAST

The total cost per kilometer is the sum of three separate cost curves (labor, supplies, and equipment operation) for a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with drilling and blasting for access roads.

BASE CURVE

The curves are based on estimated costs for drilling and blasting a cut with a single ditch. The terrain has a side slope of 25%, and the cut contains 50% rock.

(L) Labor Operating Cost $(Y_L) = 9{,}633.822(X)^{0.496}$
The operating labor costs are distributed as follows:

Direct labor...............	79%
Maintenance labor..........	21%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Air-track driller..........	33%	$16.78
Compressor operator........	17%	17.23
Chuck tender...............	27%	13.86
Powderman..................	8%	16.33
Powderman helper...........	7%	14.56
Flatbed-truck driver.......	8%	15.89

The average wage for labor is $15.68 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 7{,}247.524(X)^{0.644}$
The supply cost consists of 79% blasting supplies and 21% drilling supplies. Drilling supplies consist of percussion drill bits, rods, striking bars, and couplings; blasting supplies consist of dynamite, ANFO, electric blasting caps, and connecting wire.

(E) Equipment Operating Cost $(Y_E) = 4{,}109.384(X)^{0.496}$
The equipment operating cost consists of 51% for repair parts, 48% for fuel and lubrication, and 1% for tires.

The equipment operation curve consists of

Air-track drills...........	33%
Portable compressors.......	55%
Flatbed truck..............	7%
Pickup truck...............	5%

The equipment operating cost distribution is:

	Repair parts	Fuel and lube	Tires
Air-track drills...........	93%	7%	-
Portable compressors.......	34%	65%	1%
Flatbed truck..............	9%	80%	11%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Rock Factor For drilling and blasting cuts that contain other than 50% rock, multiply the curves by the following factors:

For drilling and blasting cuts containing 25% rock,

Rock factor $(F_{R\ 25\%}) = 0.6$

For drilling and blasting cuts containing 100% rock,

Rock factor $(F_{R\ 100\%}) = 1.4$

Side Slope Factor For terrain with side slopes of 0% to 20% that require drilling and blasting for two ditches and for providing material for a minimum fill, the base curve costs should be used without any adjustments. For terrain with side slopes other than 0% to 20% multiply the cost obtained from the curves by the following factors:

For clearing on terrain with side slopes of 20% to 50%,

Side slope factor $(F_{S\ 20\%-50\%}) = 1.5$

On terrain with side slopes in the range of 50% to 100%,

Side slope factor $(F_{S\ 50\%-100\%}) = 3.0$

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation value by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

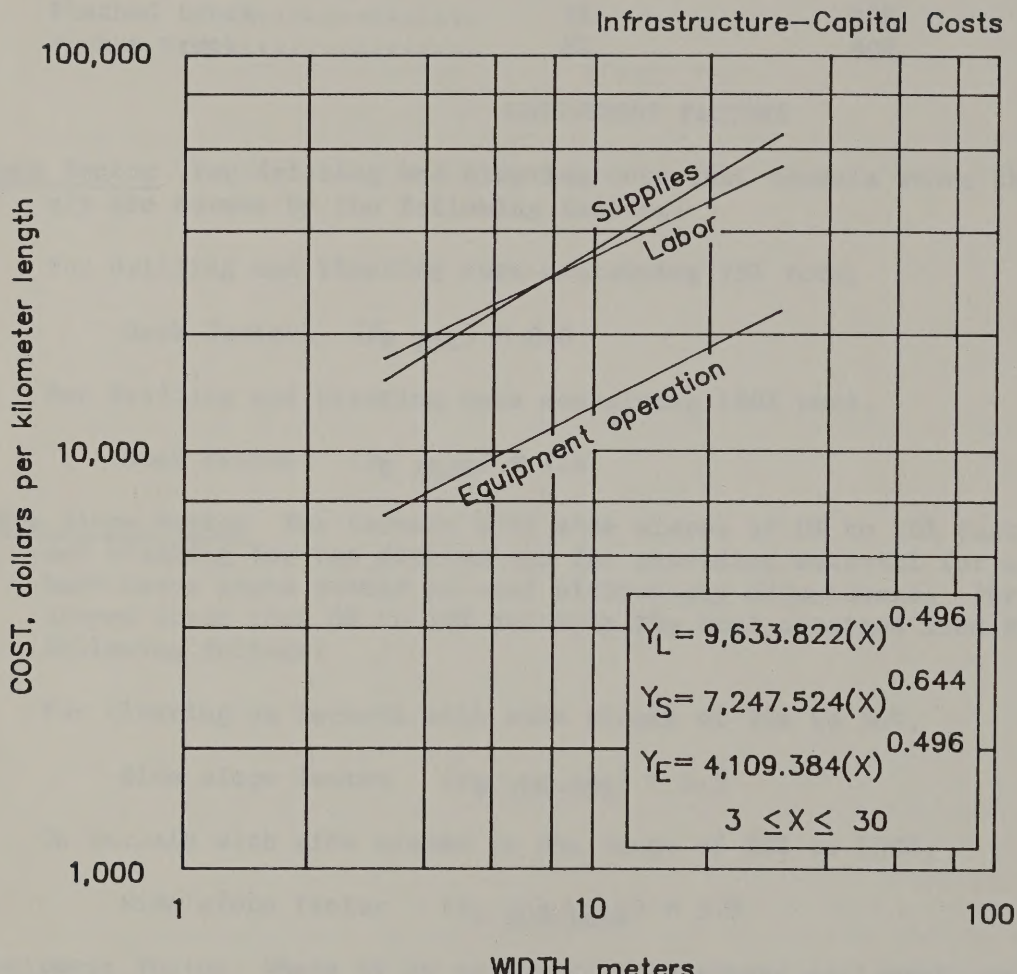
Shifts per day.............	1	2	3
Factor.....................	2.12	1.84	1.75

<u>Subcontractor Factor</u> If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs by the following factors:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



8.1.1.2. Access roads
DRILL AND BLAST

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.1. ACCESS ROADS

8.1.1.3. EXCAVATION

The total cost per kilometer is the sum of two separate cost curves (labor and equipment operation) having a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with excavation for access roads.

BASE CURVES

The curves are based on a dozer excavation operation that is working on terrain with a side slope of 25%, side-casting from cuts or ditches to a 30-cm fill or to waste. The material to be excavated is either blasted rock or a common conglomerate that presents some difficulty in cutting and drifting.

(L) Labor Operating Cost $(Y_L) = 29.843(X)^{1.870}$

The operating labor costs are distributed as follows:

Direct labor...............	60%
Maintenance labor..........	40%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Dozer operator.............	60%	$16.33
Grader operator............	20%	16.33
Water-truck driver.........	20%	15.89

The average wage for labor is $16.24 per worker-hour (including burden and average shift differential).

(E) Equipment Operating Cost $(Y_E) = 27.128(X)^{1.870}$

The equipment operating cost consists of 46% for repair parts, 50% for fuel and lubrication, and 4% for tires.

The equipment operation curve consists of

Dozer crawlers.............	47%
Dozer-ripper crawler.......	25%
Motor grader...............	15%
Water truck................	9%
Pickup truck...............	4%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Dozer crawlers	51%	49%	-
Dozer ripper crawler	53%	47%	-
Motor grader	45%	41%	14%
Water truck	29%	55%	16%
Pickup truck	8%	90%	2%

ADJUSTMENT FACTORS

Side Slope Factor On terrain with a side slope other than 20% to 30%, multiply the costs obtained from the curves by the following factors:

For clearing on terrain with side slopes of 0% to 20%,

Side slope factor $(F_{S\ 0\%-20\%}) = [0.8(S)]^{0.600}(W)^{0.756}$
where S = side slope [defined as 1 + (percent slope/100)],
and W = roadway width, in meters.

For clearing on terrain with side slopes of 30% to 100%,

Side slope factor $(F_{S\ 30-100\%}) = [0.8(S)]^{3.958}(W)^{0.087}$
where S = side slope [defined as 1 + (percent slope/100)],
and W = roadway width, in meters.

Material Factor For excavation of materials that are easy to cut and drift, multiply the costs obtained from the curves by the following factors:

Material factor $(F_{M\ EASY}) = 0.75$

For excavation of extremely wet and sticky material, multiply the curves by the following factors:

Material factor $(F_{M\ DIFFICULT}) = 1.33$

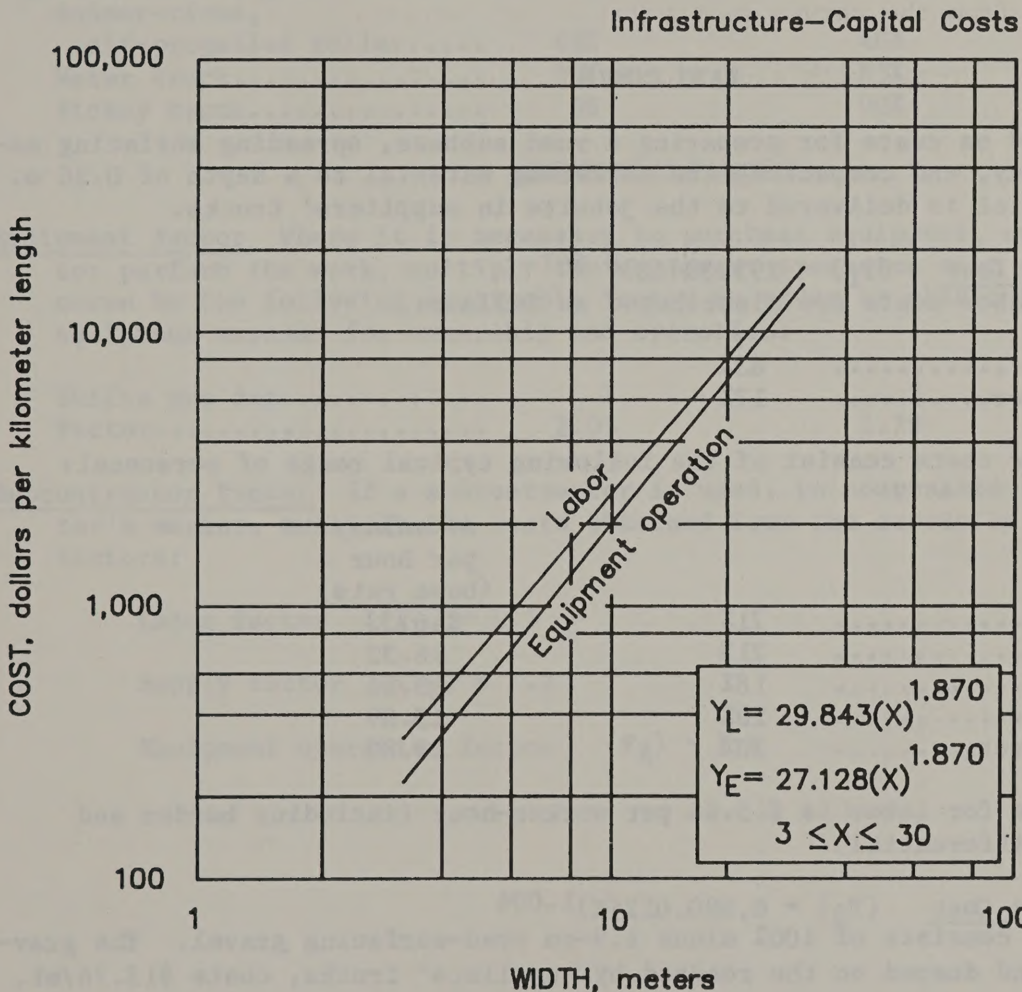
Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

Shifts per day.............	1	2	3
Factor.....................	1.94	1.71	1.63

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.5$

Equipment operation factor $(F_E) = 1.2$



8.1.1.3. Access roads
EXCAVATION

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.1. ACCESS ROADS

8.1.1.4. GRAVEL SURFACING

The total cost per kilometer is the sum of three separate cost curves (labor, supplies, and equipment operation) for a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with gravel surfacing of access roads.

BASE CURVE

The curves are based on costs for preparing a road subbase, spreading surfacing material on the roadway, and compacting the surfacing material to a depth of 0.20 m. The surfacing material is delivered to the jobsite in suppliers' trucks.

(L) Labor Operating Cost $(Y_L) = 293.304(X)^{0.667}$
The operating labor costs are distributed as follows:

Direct labor...............	83%
Maintenance labor..........	17%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Grader operator............	21%	$16.33
Roller operator............	21%	16.33
Dumpman....................	18%	13.86
Grade checker..............	20%	15.89
Water-truck driver.........	20%	15.89

The average wage for labor is $15.66 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 6{,}880.012(X)^{1.006}$
The supply cost consists of 100% minus 1.9-cm road-surfacing gravel. The gravel, delivered and dumped on the roadbed by suppliers' trucks, costs $13.76/mt.

(E) Equipment Operating Cost $(Y_E) = 135.032(X)^{0.667}$
The equipment operating cost consists of 37% for repair parts, 51% for fuel and lubrication, and 12% for tires.

The equipment operation curve consists of

Motor grader...............	42%
Rubber-tired, self-propelled roller.....	19%
Water truck................	26%
Pickup truck...............	13%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Motor grader...............	45%	41%	14%
Rubber-tired, self-propelled roller.....	49%	40%	11%
Water truck................	29%	55%	16%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

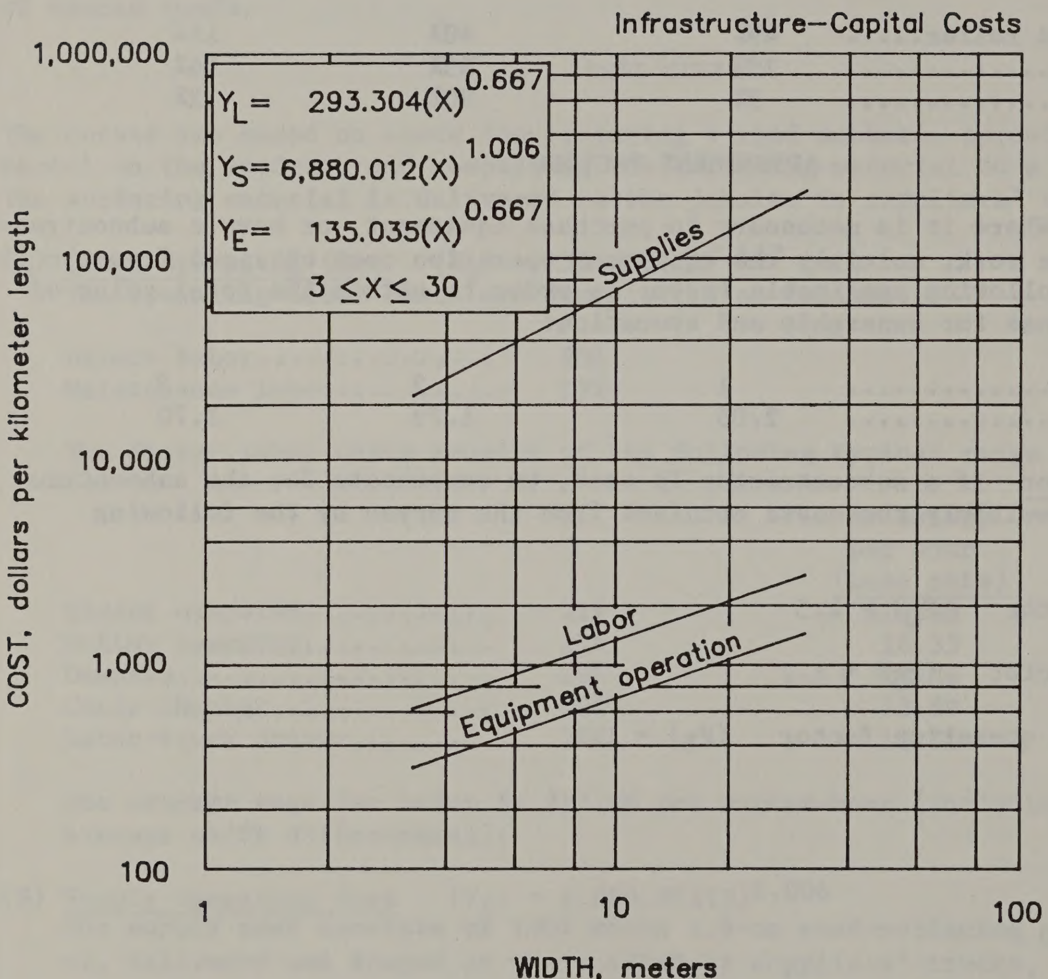
Shifts per day.............	1	2	3
Factor.....................	2.05	1.79	1.70

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor (F_L) = 1.5

Supply factor (F_S) = 1.2

Equipment operation factor (F_E) = 1.2



8.1.1.4. Access roads
GRAVEL SURFACING

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.1. ACCESS ROADS

8.1.1.5. PAVING

The total cost per kilometer is the sum of three separate cost curves (labor, supplies, and equipment operation) for a roadway width (X), in meters. The curves are valid for widths between 3 and 30 m, operating one shift per day. This cost is multiplied by the total kilometers to obtain the capital cost. Each curve includes all of the daily operating and maintenance costs associated with paving of access roads.

BASE CURVE

The curves are based on a paving operation for laying and compacting hot-mix asphalt concrete (purchased locally from a hot-mix plant) to a depth of 5.1 cm. Costs to produce an appropriate paving road base are covered in section 8.1.1.4., gravel surfacing.

(L) Labor Operating Cost $(Y_L) = 117.710(X)^{1.005}$
The operating labor costs are distributed as follows:

Direct labor...............	80%
Maintenance labor..........	20%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Paver operator............	13%	$16.33
Roller operator............	26%	16.33
General laborer............	22%	13.86
Rear-dump truck driver.....	39%	15.89

The average wage for labor is $15.55 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 2,661.382(X)^{1.005}$
The supply cost consists of 100% asphalt concrete (minus 1.9-cm hot mix). The asphalt concrete, supplied by a local hot-mix plant, costs $26.37/mt.

(E) Equipment Operating Cost $(Y_E) = 68.436(X)^{1.005}$
The equipment operating cost consists of 32% for repair parts, 58% for fuel and lubrication, and 10% for tires.

The equipment operation curve consists of

Asphalt paver..............	20%
Rubber-tired, self-propelled roller.....	5%
Steel-wheeled, tandem roller.............	5%
Rear-dump trucks...........	64%
Pickup truck...............	6%

The equipment operating cost distribution is

	Repair parts	Fuel and lube	Tires
Asphalt paver..............	68%	32%	-
Rubber-tired, self-propelled roller.....	43%	51%	6%
Steel-wheeled, tandem roller.............	50%	50%	-
Rear-dump trucks	22%	63%	15%
Pickup truck...............	8%	90%	2%

ADJUSTMENT FACTORS

Supply Factor The supplies cost should be adjusted for changes in the base asphalt-concrete price.

Equipment Factor Where it is necessary to purchase equipment, or have a subcontractor perform the work, multiply the equipment operation cost obtained from the curve by the following applicable factor in order to obtain the total value of equipment expense for ownership and operation:

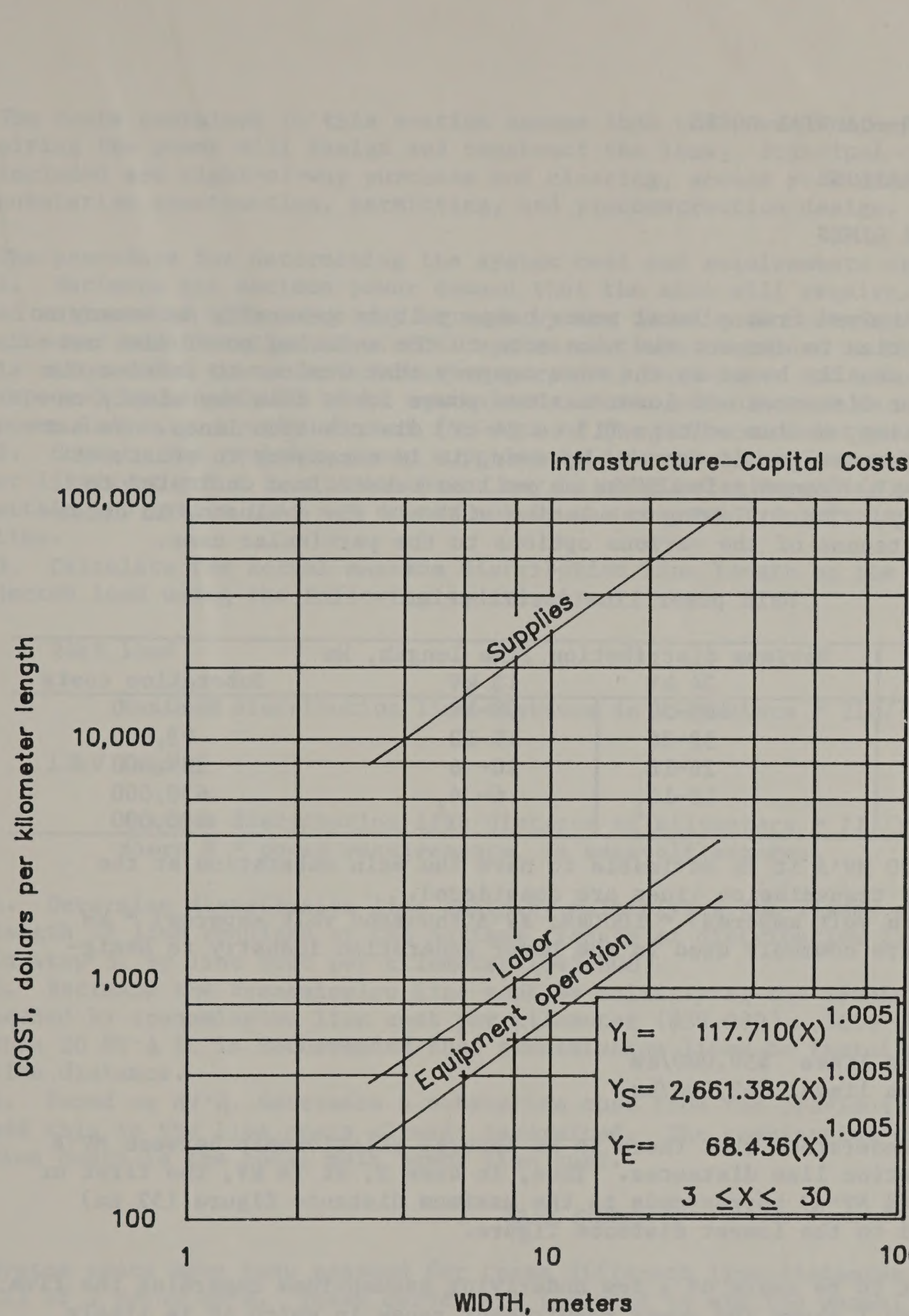
Shifts per day.............	1	2	3
Factor......................	1.44	1.33	1.29

Subcontractor Factor If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$

Equipment operation factor $(F_E) = 1.2$



8.1.1.5. Access roads
PAVING

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.2. GENERAL OPERATIONS

8.1.2.1. MAIN POWER LINES

If power is to be obtained from a local power company it is generally necessary to construct new facilities to connect the mine site to the existing power line network. This cost is usually borne by the mine company that desires to receive the service. For shorter distances and lower maximum power loads this may simply entail extending existing, medium voltage (13 to 24-kV) distribution lines. To satisfy greater loads over longer distances, however, it is necessary to construct higher voltage (115-kV) transmission lines as well as substations dedicated to serve the mine solely. The following tabulation will aid the evaluator in determining the appropriateness of the various options to the particular case.

Main power line distribution

Case	Load Range(MV•A)	Maximum distribution line length, km 24 kV	13 kV	Substation costs
1....	2- 4	105-52	38-19	$ 0
2....	4- 8	52-26	19-10	95,000
3....	8-12	26-18	10- 6	289,000
4....	12-20	18-10	6- 4	630,000
5....	20	0[1]	0[1]	630,000

[1]At greater than 20 MV•A it is advisable to have the main substation at the mine site, thus only transmission lines are considered.

Note.--MV•A(million volt amperes) = 1000kW; KV•A(thousand volt amperes) = kW Both MV•A and KV•A are commonly used in the power generation industry to designate power demand.

LINE COSTS:

Transmission lines	$59,000/km
Distribution lines	$42,000/km

It is important to understand that there is an inverse relationship between MV•A and maximum distribution line distances. Thus, in case 2, at 24 kV, the first or lowest load figure (4 MV•A) corresponds to the maximum distance figure (52 km) and the highest load to the lowest distance figure.

It is also important to be aware of a few underlying assumptions regarding the five separate cases. Case 1 shows the power requirement range in which it is likely that existing distribution lines could supply the needed power. Thus there is no substation expense. The second and third cases assume that minor and major modifications of an existing substation will be required, respectively. They also assume that new line needed will originate from that modified substation. For cases 4 and 5 the large power requirements necessitate the construction of a completely new, dedicated substation. This facility will thus have to be fed by extending an existing high voltage, transmission line. In the instance of case 4 the site of the substation is as near the existing transmission line network as practicable; for case 5 the substation is assumed to be at the mine site.

The costs contained in this section assume that the power company that will be supplying the power will design and construct the line. Principal costs categories included are right-of-way purchase and clearing, access road construction, line and substation construction, permitting, and preconstruction design.

The procedure for determining the system cost and requirements are as follows:
1. Estimate the maximum power demand that the mine will require. If not available an estimate of this value may be made by the techniques contained in the appropriate mine and beneficiation electrical system sections contained in this handbook. It is recommended that, for estimating purposes, horsepower and kilowatts (or kilovolt amperes) be considered to be equivalent. Motor efficiencies as well as other system power losses generally account for much of the difference between the two units.
2. Contact the probable power supplier to determine the "nearest useable source", or likeliest point from which power may be obtained. Depending upon present loading within the system this may or may not be the nearest transmission or distribution line.
3. Calculate the actual maximum distribution line length on the basis of the projected load using the following equations:

24kV load

Maximum distribution line distance in kilometers = 210/(P)

13kV load

Maximum distribution line distance in kilometers = 77/(P)
where P = power requirements, in megavolt amperes.

4. Determine distribution line costs by multiplying the lesser of either the total length of line required or the maximum length of distribution line as calculated in step 3, by line cost per kilometer ($42,000).
5. Estimate the transmission line cost by multiplying the remaining length of line needed by transmission line cost per kilometer ($59,000). Note that for greater than 20 MV•A it is recommended that transmission lines be installed for the entire distance.
6. Based on MV•A, determine a substation cost from the previous tabulation and add this to the line costs already determined. The combination of line and substation costs is the total main power line cost.

BASE CURVE

System costs have been graphed for three different line distances over the range (X) of 2 to 40 MV•A. These curves are included to aid the manual user that is interested in a very preliminary cost and desires to avoid the procedure outlined above for a more detailed cost determination.

Freight charges from the east coast manufacturing plant to Denver, CO, for the major purchased equipment has been determined to be:

Transformer - 32 mt..........................	$7,500
Oil breaker - 3 at 13 mt each.................	$9,600

All other equipment and materials are considered to be locally available in Denver.

The total capital cost is based on single curves having power loads (X), in megavolt amperes. The curves are valid for power loads of 2 to 40 MV•A.

The capital cost derived from the curve is a combination of the following costs:

	Small (2 to 20 MV•A)	Large (20 to 40 MV•A)
Construction labor cost......	50%	47%
Construction supply cost.....	50%	37%
Purchased equipment cost.....	-	16%

The 10 km main powerline capital cost is $(Y_{C\ 10\ KM\ LINE}) = 207{,}826.608(X)^{0.563}$ and is distributed as follows:

(L) Construction labor cost

$(Y_{L\ 10\ KM\ LINE-SMALL}) = 103{,}913.304(X)^{0.563}$
$(Y_{L\ 10\ KM\ LINE-LARGE}) = 97{,}678.506(X)^{0.563}$

(S) Construction supply cost

$(Y_{S\ 10\ KM\ LINE-SMALL}) = 103{,}913.304(X)^{0.563}$
$(Y_{S\ 10\ KM\ LINE-LARGE}) = 76{,}895.844(X)^{0.563}$

(E) Purchased equipment cost

$(Y_{E\ 10\ KM\ LINE-LARGE}) = 33{,}252.257(X)^{0.563}$

The 25km main powerline capital cost is $(Y_{C\ 25\ KM\ LINE}) = 644{,}990.250(X)^{0.370}$ and is distributed as follows:

(L) Construction labor cost

$(Y_{L\ 25\ KM\ LINE-SMALL}) = 322{,}495.125(X)^{0.370}$
$(Y_{L\ 25\ KM\ LINE-LARGE}) = 303{,}145.418(X)^{0.370}$

(S) Construction supply cost

$(Y_{S\ 25\ KM\ LINE-SMALL}) = 322{,}495.125(X)^{0.370}$
$(Y_{S\ 25\ KM\ LINE-LARGE}) = 238{,}646.392(X)^{0.370}$

(E) Purchased equipment cost

$(Y_{E\ 25\ KM\ LINE-LARGE}) = 103{,}198.440(X)^{0.370}$

The 50km main powerline capital cost is $(Y_{C\ 50\ KM\ LINE}) = 1{,}526{,}363.387(X)^{0.278}$ and is distributed as follows:

(L) Construction labor cost

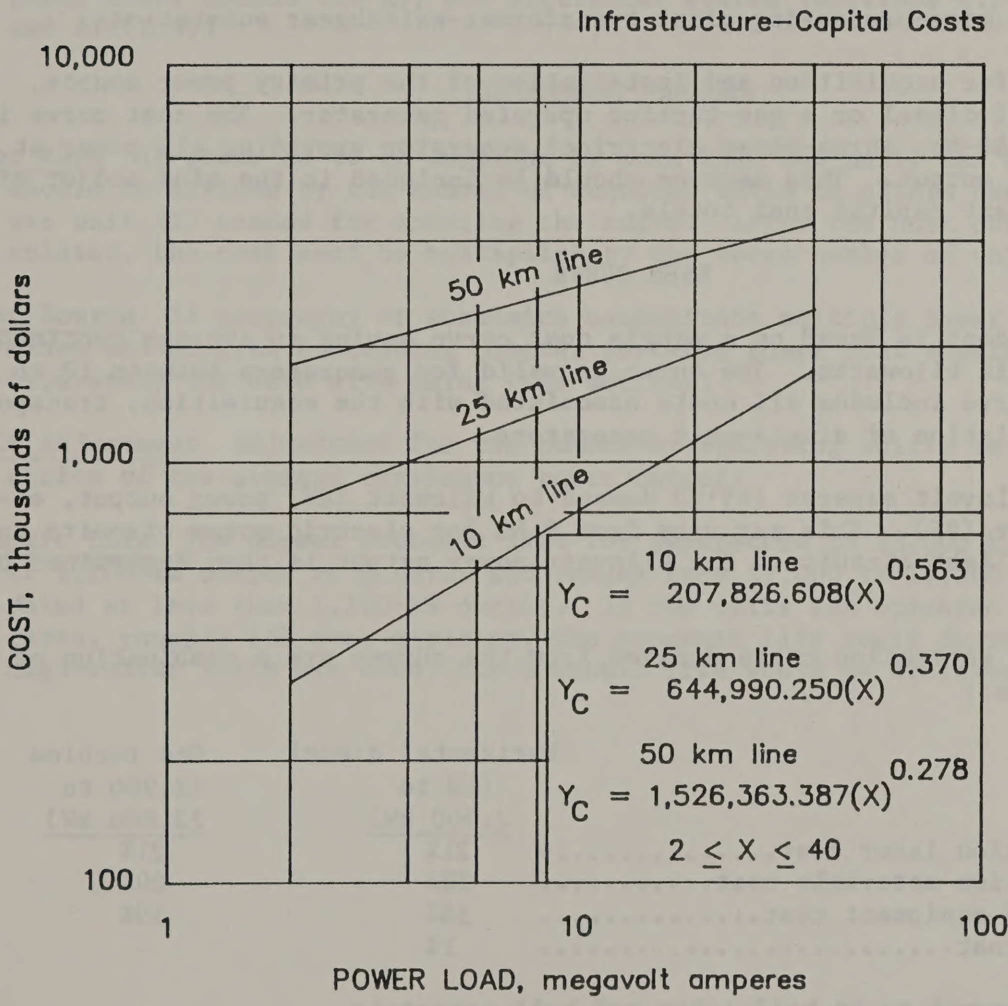
$(Y_{L\ 50\ KM\ LINE-SMALL}) = 763{,}181.694(X)^{0.278}$
$(Y_{L\ 50\ KM\ LINE-LARGE}) = 717{,}390.792(X)^{0.278}$

(S) Construction supply cost

$(Y_{S\ 50\ KM\ LINE-SMALL}) = 763{,}181.694(X)^{0.278}$
$(Y_{S\ 50\ KM\ LINE-LARGE}) = 564{,}754.453(X)^{0.278}$

(E) Purchased equipment cost

$(Y_{E\ 50\ KM\ LINE-LARGE}) = 244{,}218.142(X)^{0.278}$



8.1.2.1. Main power lines

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.2. GENERAL OPERATIONS

8.1.2.2. PORTABLE POWER GENERATION

This section is to be used in conjunction with section 9.1.2.2. when electrical power is unavailable through a commercial power utility company or when it would be uneconomical to run power distribution facilities to the user. No adjustments are necessary for the mine or mineral processing plant electrical system (sections 2.2.4.2. and 4.2.5.3., (IC 9142) and 6.1.8.4.) because output power matches the power input to the mine-processing plant transformer-switchgear substations.

The cost shown is for acquisition and installation of the primary power source, either a horizontal-diesel or a gas-turbine operated generator. The cost curve is based on a single 60-Hz, three-phase electrical generator providing all power at the rated kilowatt output. This section should be included in the mine and/or mineral processing plant capital cost totals.

BASE CURVE

The total capital cost is based on a single cost curve having an average continuous power output (X), in kilowatts. The curve is valid for generators between 18 to 23,600 kW. The curve includes all costs associated with the acquisition, transportation, and installation of single-unit generators.

To convert from kilovolt amperes (kV•A) demand to kilowatt (kW) power output, estimate power factor (PF). This may vary from 0.80 for electric motor circuits to 1.00 for electric light circuits. The kilowatt power output is then determined by kV•A X PF = kW.

The portable power generation costs derived from the curves are a combination of the following costs::

	Horizontal diesel (18 to 2,900 kW)	Gas turbine (2,900 to 23,600 kW)
Installation labor cost...............	21%	21%
Installation materials cost...........	20%	20%
Purchased equipment cost..............	58%	59%
Freight cost..........................	1%	-

Installation is assumed to be half labor and half materials.

The total diesel-powered portable power generation capital cost is ($Y_{C\ DIESEL}$) = $797.574(X)^{0.876}$ and is distributed as follows:

(L) Construction labor cost ($Y_{L\ DIESEL}$) = $167.491(X)^{0.876}$

(S) Construction supply cost ($Y_{S\ DIESEL}$) = $159.514(X)^{0.876}$

(E) Purchased equipment cost ($Y_{E\ DIESEL}$) = $470.568(X)^{0.876}$

The total turbine-powered portable power generation capital cost is $(Y_{C\ TURBINE}) = 2{,}251.219(X)^{0.872}$ and is distributed as follows:

(L) Construction labor cost $(Y_{L\ TURBINE}) = 472.756(X)^{0.872}$

(S) Construction supply cost $(Y_{S\ TURBINE}) = 450.244(X)^{0.872}$

(E) Purchased equipment cost $(Y_{E\ TURBINE}) = 1328.219(X)^{0.872}$

Power Output Determination For surface mine power output (kW), see electrical system (section 2.2.4.2. (IC 9142)). For underground mine and mineral processing plant power demand (kV·A), see electrical system (sections 4.2.5.3. (IC 9142) and 6.1.8.4.)

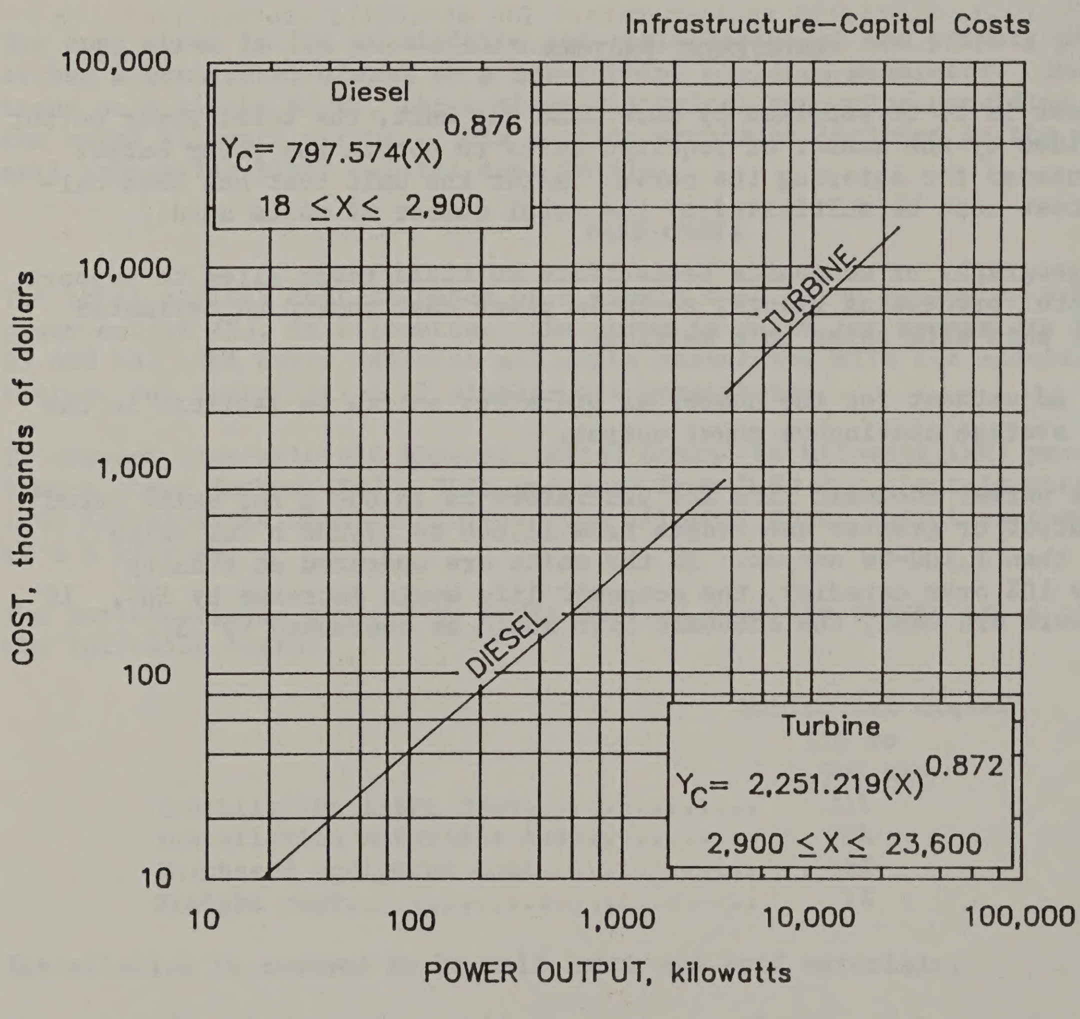
ADJUSTMENT FACTORS

Power Rate If power is to be supplied by more than one unit, the total power output should be divided by the number of required units to obtain the power output per unit (X) needed for entering the curve. After the unit cost has been calculated, the cost must be multiplied by the total number of units used.

Power Source If geography or economics necessitate multiple power sites to support mines and mineral processing plants, portable power cost should be estimated separately for each site using this section.

Shift Adjustment Adjustment for the number of operating shifts is implicit in the choice of the average continuous power output.

Economic Life The normal economic life for generators is 25,000 h for units rated at 1,100-kW output or greater and ranges from 11,000 to 17,500 h for units rated at less than 1,100-kW output. If the units are operated at standby rates, roughly 10% over capacity, the economic life would decrease by 50%. If high-sulfur fuels are used, the economic life would be decreased by 25%.



8.1.2.2. Portable power generation

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.2. GENERAL OPERATIONS

8.1.2.3. STOCKPILE STORAGE FACILITIES

A stockpile storage facility provides sufficient storage capacity for a material until it can be further processed. A storage facility may also provide adequate reserve material to dampen surges in the material supply. Examples of materials stockpiled are smelter flux, coal, and coarse ore. For this base curve, capital cost is correlated to the live storage capacity of the stockpile facility. Live storage capacity of a stockpile is normally about 25% of the total stockpile capacity and 150% of the daily stockpile reclaim rate. The stockpile storage facility capital cost includes all costs associated with acquisition and installation of stockpiling conveyors, reclaim tunnels, reclaim feeders, and reclaim conveyors.

BASE CURVE

The total capital cost is based on a single cost curve having a live storage capacity (X), in metric tons. The curve is valid for 3,000 to 300,000 mt, operating two shifts per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	13%
Construction supply cost.....	36%
Purchased equipment cost.....	51%

A typical breakdown of the major cost components is

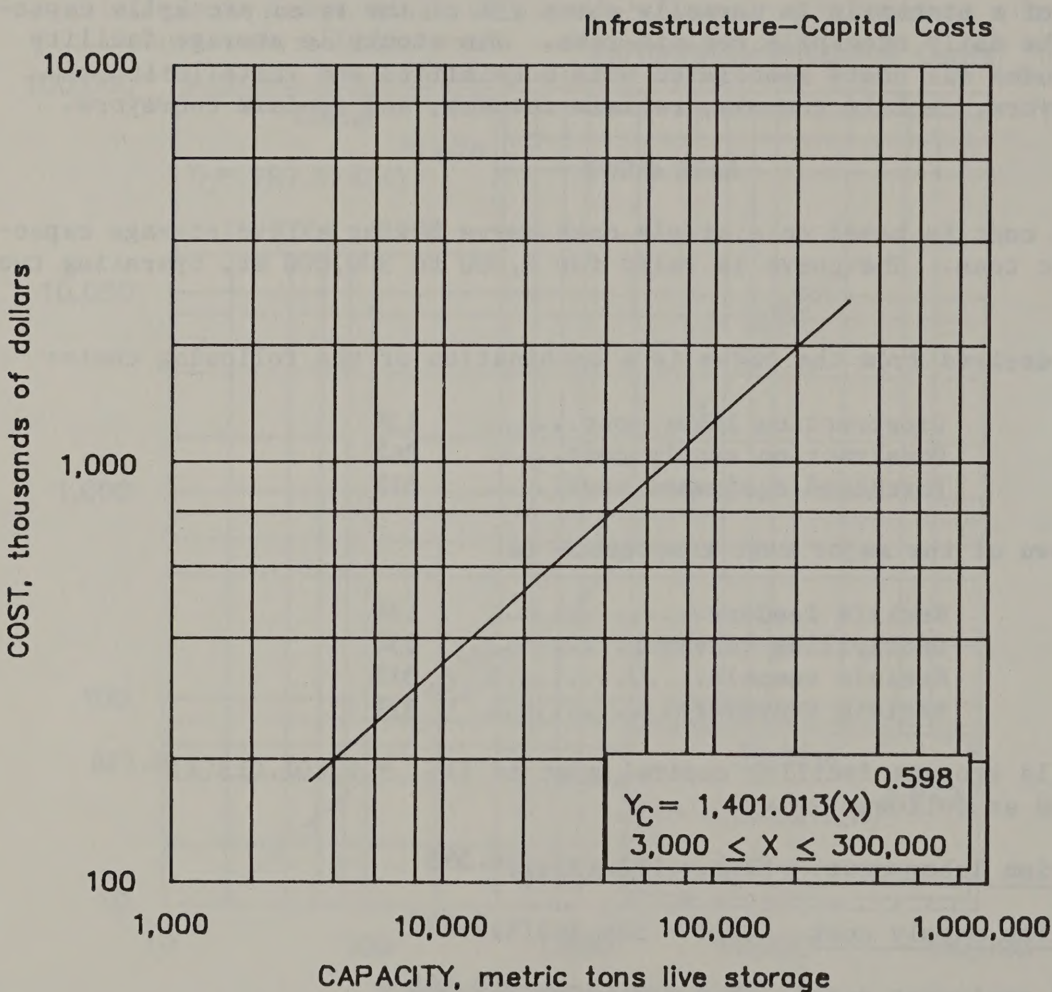
Reclaim feeders..............	14%
Stockpiling conveyor.........	23%
Reclaim tunnels..............	31%
Reclaim conveyors............	32%

The total stockpile storage facility capital cost is $(Y_C) = 1,401.013(X)^{0.598}$ and is distributed as follows:

(L) Construction labor cost $(Y_L) = 182.132(X)^{0.598}$

(S) Construction supply cost $(Y_S) = 504.365(X)^{0.598}$

(E) Purchased equipment cost $(Y_E) = 714.516(X)^{0.598}$



8.1.2.3. Stockpile storage facilities

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.3. LOADING FACILITIES

8.1.3.1. LOAD-OUT FACILITIES

Load-out facility capital costs are based on the equipment needed to transport, store, and load-out for shipment concentrates from a mill via truck or train. Total storage capacity is equal to 2 days production of the concentrate from the mill. The load-out facility capital cost includes all costs associated with acquisition and installation of conveyors, storage bins, and bucket elevators. This curve is chiefly applicable to low-grade deposits, such as copper or molybdenum deposits. As such, it will cover operations which mine between 2,000 and 60,000 mt of ore per day. The total capital cost is based on a single cost curve having on a production rate (X), in metric tons of concentrate transferred from a mill to storage bins in a 24-h period. The curve is valid for operations between 150 and 1,500 mtpd, operating one shift per day.

BASE CURVE

The load-out facility capital cost derived from the curve is a combination of the following costs:

Construction labor cost........	11%
Construction supply cost.......	31%
Purchased equipment cost.......	58%

A typical breakdown of the load-out facility's major cost components is

Bins and activators...........	78%
Bucket elevators..............	7%
Conveyors.....................	15%

The total load-out facility capital cost is $(Y_C) = 5{,}923.123(X)^{0.568}$ and is distributed as follows:

(L) <u>Construction labor cost</u> $(Y_L) = 651.543(X)^{0.568}$

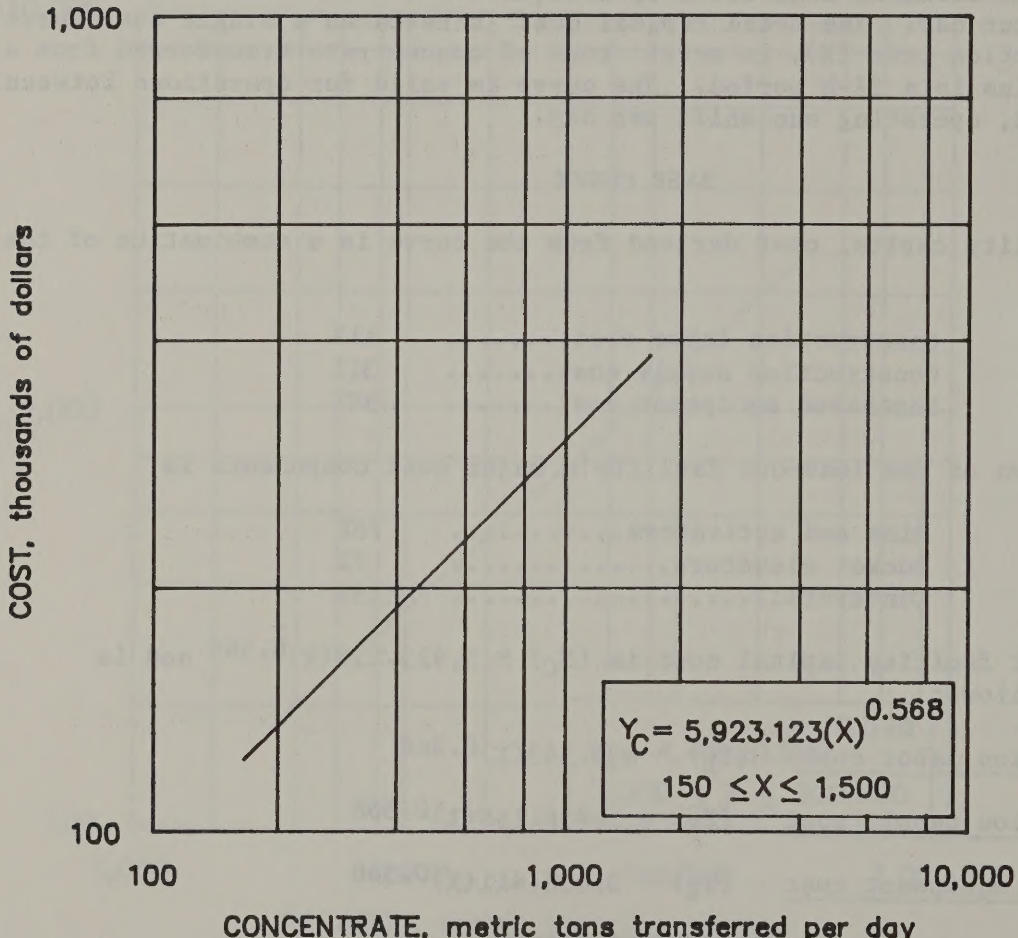
(S) <u>Construction supply cost</u> $(Y_S) = 1{,}836.168(X)^{0.568}$

(E) <u>Purchased equipment cost</u> $(Y_E) = 3{,}435.411(X)^{0.568}$

ADJUSTMENT FACTOR

<u>Secondary Concentrate Loadout</u> Milling operations often recover and concentrate secondary minerals such as molybdenum and uranium. The quantities recovered are seldom large in comparison to the primary mineral, running between less than 1 up to 125 mt per day. The basic facilities used for loading out such material usually consist of a small storage bin, a vibrating conveyor for filling 37 to 55 gal drums, a roller conveyor for transporting drums, and a fork-lift for loading drums into trucks or rail cars. These types of facilities are not included in this cost curve. If such operations occur at the proposed mill, the curve must be adjusted accordingly.

Infrastructure—Capital Costs



8.1.3.1. Loading facilities
LOAD—OUT FACILITIES

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.3. LOADING FACILITIES

8.1.3.2. OFF-LOADING FACILITIES

Off-loading facility capital costs are based on installation of equipment used in transporting ore from a reception point to storage bins adjacent to the mill during a two-shift-per-day operation. Storage capacity is between 800 and 12,000 mt of ore. Examples of the types of material stored would be coarse metallic ore, crushed limestone, and coal. For situations where larger storage facilities are needed, see the section 8.1.2.3., stockpile storage facilities. Off-loading facility capital costs includes all costs associated with acquisition and installation of the conveyors, feeders, and storages bins required for this task.

The total capital cost is based on a single cost curve having on a production rate (X), in metric tons of ore off-loaded and stored in bins for use by the mill per day. The curves are valid for operations between 800 and 12,000 mtpd, operating two shifts per day.

BASE CURVE

The off-loading facility capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	43%
Construction supply cost.....	45%
Purchased equipment cost.....	12%

A typical breakdown of the off-loading facility's major cost components is

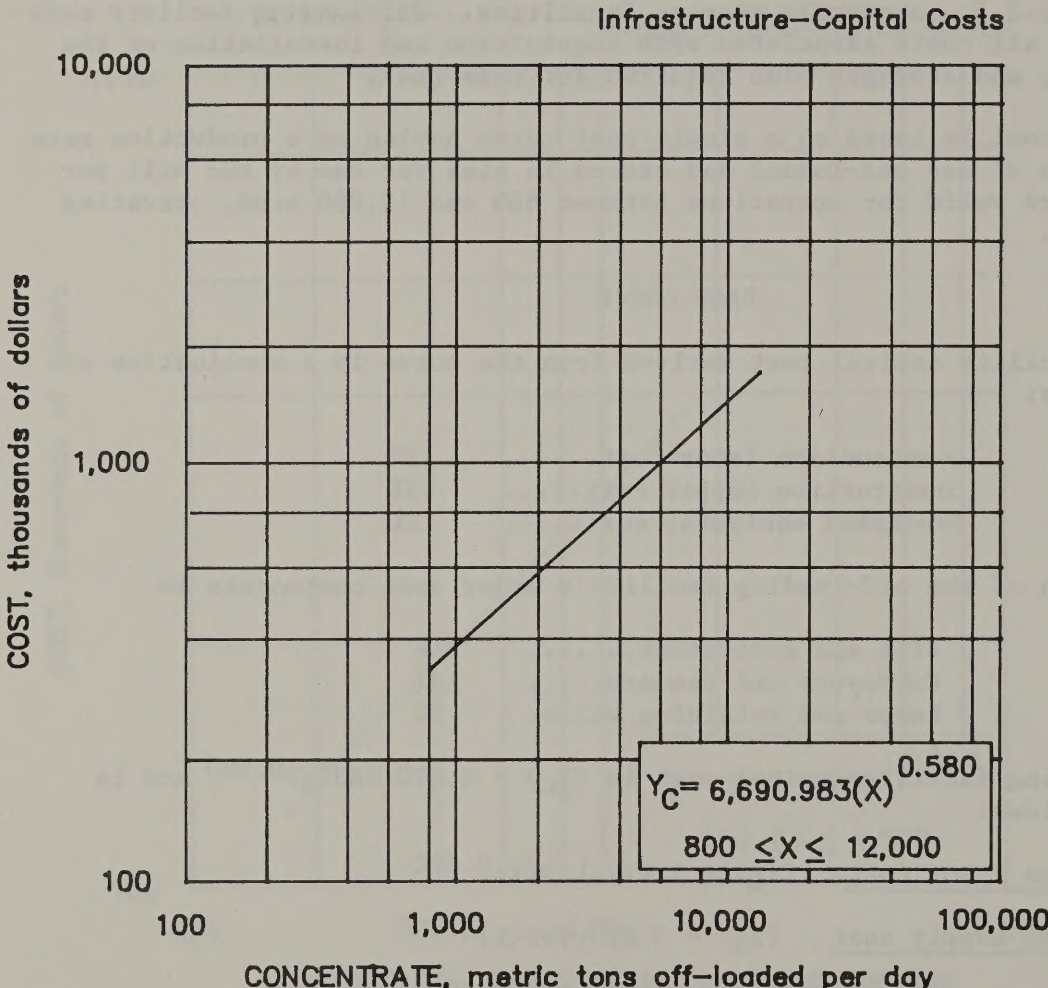
Bins and activators.......	84%
Conveyors and feeders.....	13%
Ramps and retaining walls.	3%

The total off-loading facility capital cost is $(Y_C) = 6{,}690.983(X)^{0.580}$ and is distributed as follows:

(L) Construction labor cost $(Y_L) = 2{,}877.123(X)^{0.580}$

(S) Construction supply cost $(Y_S) = 3{,}010.942(X)^{0.580}$

(E) Purchased equipment cost $(Y_E) = 802.918(X)^{0.580}$



8.1.3.2. Loading facilities
OFF-LOADING FACILITIES

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.4. TRANSPORTATION

8.1.4.1. AERIAL TRAMWAY

The capital cost curve for the aerial tramway is for the acquisition and installation of equipment for transporting ore or waste material over a slope distance of 3.0 km at a slope angle of 15°. The bulk density of the material was assumed at 1,442.5 kg/m^3 (92.0 lb/ft^3). The aerial tramway system includes loading bin, apron feeders, tram cars, track and haulage ropes, loading and unloading terminals, anchor towers, intermediate (pivoted) towers and the driving unit(s).

The total capital cost is based on a single cost curve having a tramming rate (X), in metric tons of material moved per day. The curve is valid for a production range of 2,040 to 13,800 mtpd, operating three shifts per day. The curve includes all costs associated with the acquisition and installation of the equipment required for loading, unloading, tramming, and driving units.

BASE CURVE

The capital cost derived from the curve is a combination of the following costs:

Installation labor cost.......	19.0%
Installation materials cost...	4.8%
Purchased equipment cost......	73.5%
Transportation cost...........	2.7%

The total aerial tramway capital cost is $(Y_C) = 208{,}182.537(X)^{0.385}$ and is distributed as follows:

(L) <u>Construction labor cost</u> $(Y_L) = 39{,}554.682(X)^{0.385}$

(S) <u>Construction supply cost</u> $(Y_S) = 9{,}992.762(X)^{0.385}$

(E) <u>Purchased equipment cost</u> $(Y_E) = 158{,}635.093(X)^{0.385}$

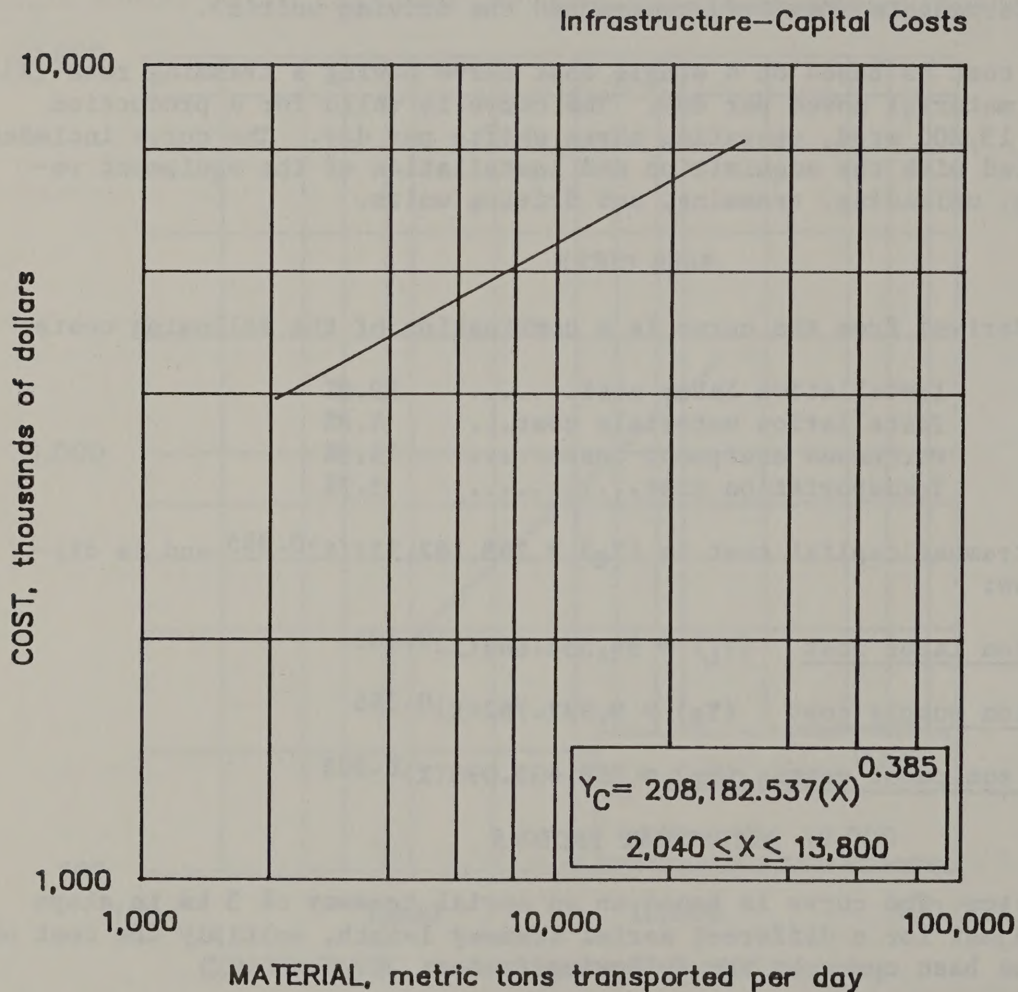
ADJUSTMENT FACTORS

<u>Tramway Length Factor</u> The curve is based on an aerial tramway of 3 km in slope length. To adjust for a different aerial tramway length, multiply the cost obtained from the base curve by the following factor:

Length factor $(Y_L) = 0.233(L)+0.302$
where L = slope length, in kilometers (not to exceed 20 km).

<u>Bulk Density Factor</u> The base curve was calculated with a material bulk density of 1,442.5 kg/m^3 (92 lb/ft^3). To adjust the base curve for a different bulk density, multiply the base curve by the following factor:

Bulk density factor $(Y_D) = 1.043-[0.00003(D)]$
where D = bulk density, in kilograms per cubic meter.



8.1.4.1. Aerial tramway

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.4. TRANSPORTATION

8.1.4.2. AIRSTRIP CONSTRUCTION

Airstrip construction cost curves give the cost per meter length of basic utility airstrips varying in width from 10 meters to 40 m. The airstrip described accommodates light single-engine and small twin-engine airplanes used for personal and business purposes, plus a broader spectrum of small business and air taxi-type twin-engine airplanes. These aircraft include the Cessna 150 series, Piper PA-32-300 Commander Six, Rockwell International 114 Commander, Beech B55 Baron, Cessna 310, and Piper PA-23-250 Aztec.

BASE CURVE

The total capital cost per meter length is based on a single cost curve having an airstrip width (X), in meters. The curve is valid for widths of 10 to 40 m, operating one shift per day. Two surface options are offered, aggregate and asphalt. Not included in this curve are costs for acquisition or clearing of airstrip site, and hauling or rough leveling of fill materials. Both aggregate and bituminous asphalt strips include base preparation (grading and rolling). The aggregate surface includes a base course of 1.9-cm stone, 15 cm deep followed by final grading and rolling. The asphalt surface consists of 31.9-cm stone 10.2 cm deep underlying 3.8-cm rolled asphalt. No equipment capital costs are incurred. A 5% contingency of total capital cost covers ancillary airstrip facilities such as gas storage and pump, airstrip end and lateral markings, wind direction apparatus, and one T-hangar as needed.

The capital cost derived from the curve is a combination of the following costs:

	Aggregate	Asphalt
Construction labor cost.......	20%	16%
Construction materials cost...	80%	84%

The total asphalt airstrip capital cost is $(Y_{C\ ASPHALT}) = 5.686(X)^{1.000}$ and is distributed as follows:

(L) Labor operating cost $(Y_{L\ ASPHALT}) = 0.910(X)^{1.000}$

(S) Supply operating cost $(Y_{S\ ASPHALT}) = 4.776(X)^{1.000}$

The total aggregate airstrip capital cost is $(Y_{C\ AGGREGATE}) = 3.471(X)^{1.005}$ and is distributed as follows:

(L) Labor operating cost $(Y_{L\ AGGREGATE}) = 0.694(X)^{1.005}$

(S) Supply operating cost $(Y_{S\ AGGREGATE}) = 2.776(X)^{1.005}$

ADJUSTMENT FACTORS

Runway Length Factor Runway length requirement is primarily dependent on anticipated aircraft use, temperature, and elevation. Aircraft type used in the cost

curve is described above. For convenience, an equation was derived to determine length requirement when the elevation of the airstrip is known. The equation is based on maximum temperature of 38C (100F). To adjust the base curve for different lengths and elevations, multiply the cost obtained from the base curve by the following factor:

Runway length $L = 891.915e^{(0.0005)(E)}$
where L = airstrip length, in meters,
and E = elevation, in meters.

Runway Width Runway width requirement varies with wingspan of anticipated aircraft using the airstrip. An 18 m wide landing strip will accommodate the aircraft mentioned. This width is advised for airstrip predesign costing. Actual width should be used when calculating capital costs of existing airstrips.

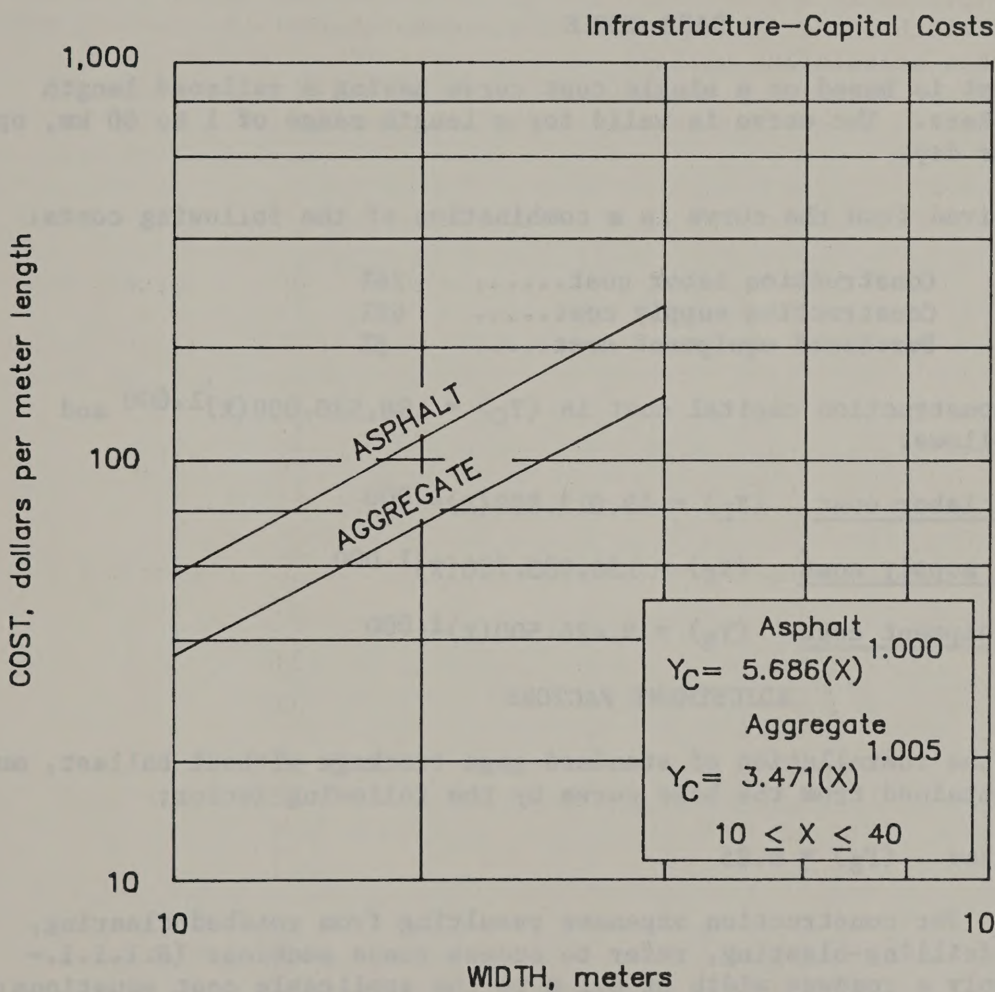
Land Requirements Factor For estimation of land acquisition and clearing requirements for airstrip landing area (includes airstrip pad, and lateral-terminal clearances), use the following equation:

Land area requirement in hectares $A = 0.012(L)+1.820$
where L = airstrip length, in meters.

Subcontractor Factor If a subcontractor is used, multiply the curves by the following factors:

Labor factor $(F_L) = 1.5$

Supply factor $(F_S) = 1.2$



8.1.4.2. Airstrip construction

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.4. TRANSPORTATION

8.1.4.4. RAILROAD CONSTRUCTION

The cost in this section covers the capital expense for laying standard-gage trackage for main lines and spurs. The cost reflects railway installation by a crew that works on a one-shift-per-day schedule; furthermore, the cost is based on trackage that is fully ballasted.

BASE CURVE

The total capital cost is based on a single cost curve having a railroad length (X), in total kilometers. The curve is valid for a length range of 1 to 60 km, operating one shift per day.

The capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	26%
Construction supply cost.....	69%
Purchased equipment cost.....	5%

The total railroad construction capital cost is $(Y_C) = 188{,}530.000(X)^{1.000}$ and is distributed as follows:

(L) <u>Construction labor cost</u> $(Y_L) = 49{,}017.800(X)^{1.000}$

(S) <u>Construction supply cost</u> $(Y_S) = 130{,}085.700(X)^{1.000}$

(E) <u>Purchased equipment cost</u> $(Y_E) = 9{,}426.500(X)^{1.000}$

ADJUSTMENT FACTORS

<u>Ballast Factor</u> For the installation of standard-gage trackage without ballast, multiply the cost obtained from the base curve by the following factor:

Ballast factor $(F_B) = 0.85$

<u>Roadbed Construction</u> For construction expenses resulting from roadbed clearing, excavation, and drilling-blasting, refer to access roads sections (8.1.1.1.-8.1.1.3.) and apply a roadway width of 6.1 m to the applicable cost equations; the additional railway expenses so derived should then be added to this section's capital cost.

<u>Equipment Factor</u> When it is necessary to purchase equipment or to have a subcontractor perform the work, multiply the equipment operation value by the following factor in order to obtain the total value of equipment expense for ownership and operation:

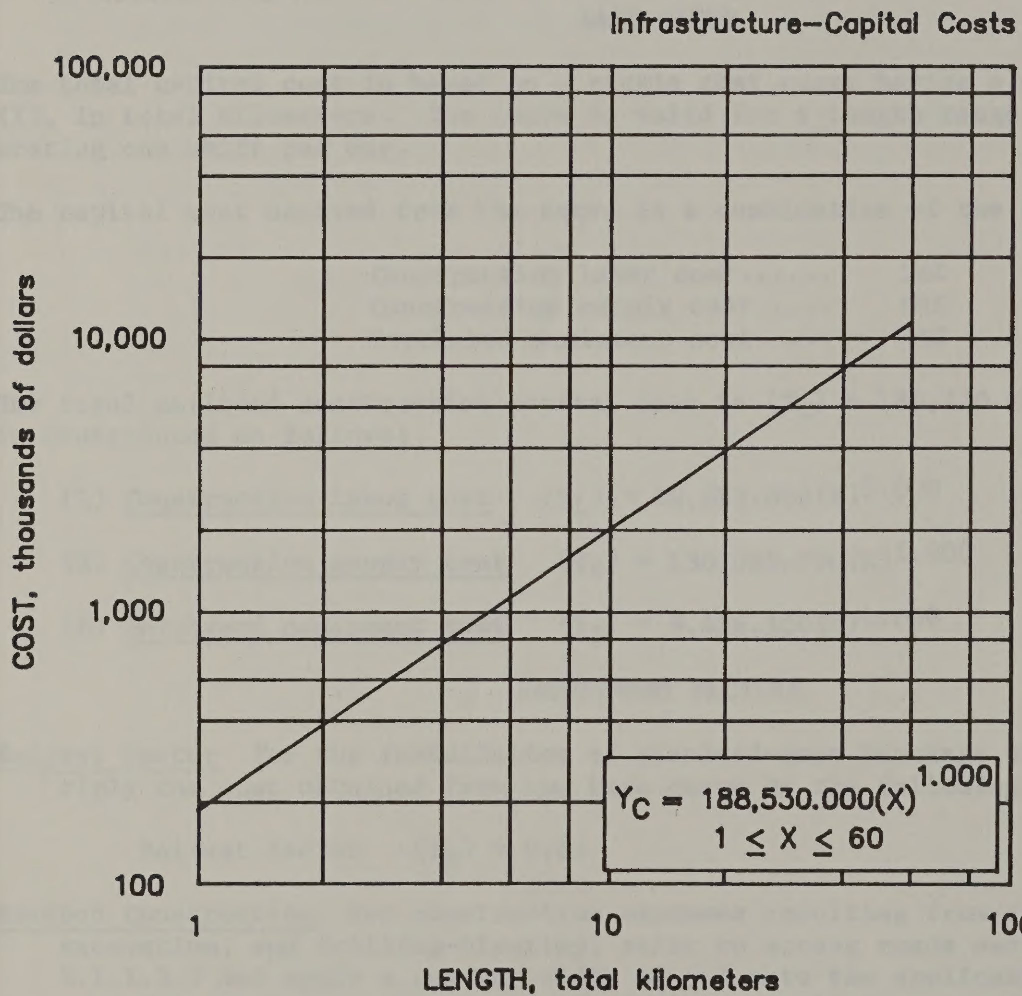
Equipment operation factor $(F_E) = 1.7$

<u>Subcontractor Factor</u> If a subcontractor is used, to compensate for the subcontractor's markup, multiply the costs obtained from the curves by the following factors:

Labor factor (F_L) = 1.5

Supply factor (F_S) = 1.2

Equipment operation factor (F_E) = 1.2



8.1.4.4. Railroad construction

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.4. TRANSPORTATION

8.1.4.5. LONG-DISTANCE SURFACE CONVEYOR

The cost curve shown is for the acquisition and erection of a long-distance surface conveyor. The conveyor is a single-flight belt conveyor made with high strength steel belting. The conveyor is designed for a 10^{o} slope and 1-km distance. Usually, the material is crushed or screened at the mine site before being conveyed. Screen and crusher capital costs are not included in this cost but are covered in separate sections.

BASE CURVE

The total cost is based on a single cost curve having a production rate (X), in metric tons per day. The curve is valid for production rates of 15,000 to 150,000 mtpd, operating three shifts per day. The curve includes all costs associated with acquisition, installation of the belt, idlers, motors, channel, and frame, and site preparation.

The long-distance surface conveyor capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	31%
Construction supply cost.....	5%
Purchased equipment cost.....	64%

A typical breakdown of a long distance surface conveyor major cost components is

Conveyor belt....................	36%
Idler assembly units.............	44%
Motors, drive trains, belt cleaners, and other mechanical items.......	20%

The total long distance surface conveyor capital cost is $(Y_C) = 81,292.281(X)^{0.309}$ and is distributed as follows:

(L) Construction labor cost $(Y_L) = 25,200.607(X)^{0.309}$

(S) Construction supply cost $(Y_S) = 4,064.614(X)^{0.309}$

(E) Purchased equipment cost $(Y_E) = 52,027.060(X)^{0.309}$

ADJUSTMENT FACTORS

Shift Adjustment The curve is based on a three-shift operation. To adjust the capital cost for a different number of daily operating shifts, multiply the actual daily tonnage (X) by the ratio of the base number of shifts (three) divided by the number of desired shifts. Then, use this modified tonnage in place of (X) in the above cost equation to obtain the adjusted cost.

Conveyor Length and Slope Factor The conveyor is 1-km long and has a 10^o slope. For other lengths and slopes, multilpy the cost obtained from the base curve by the following factor:

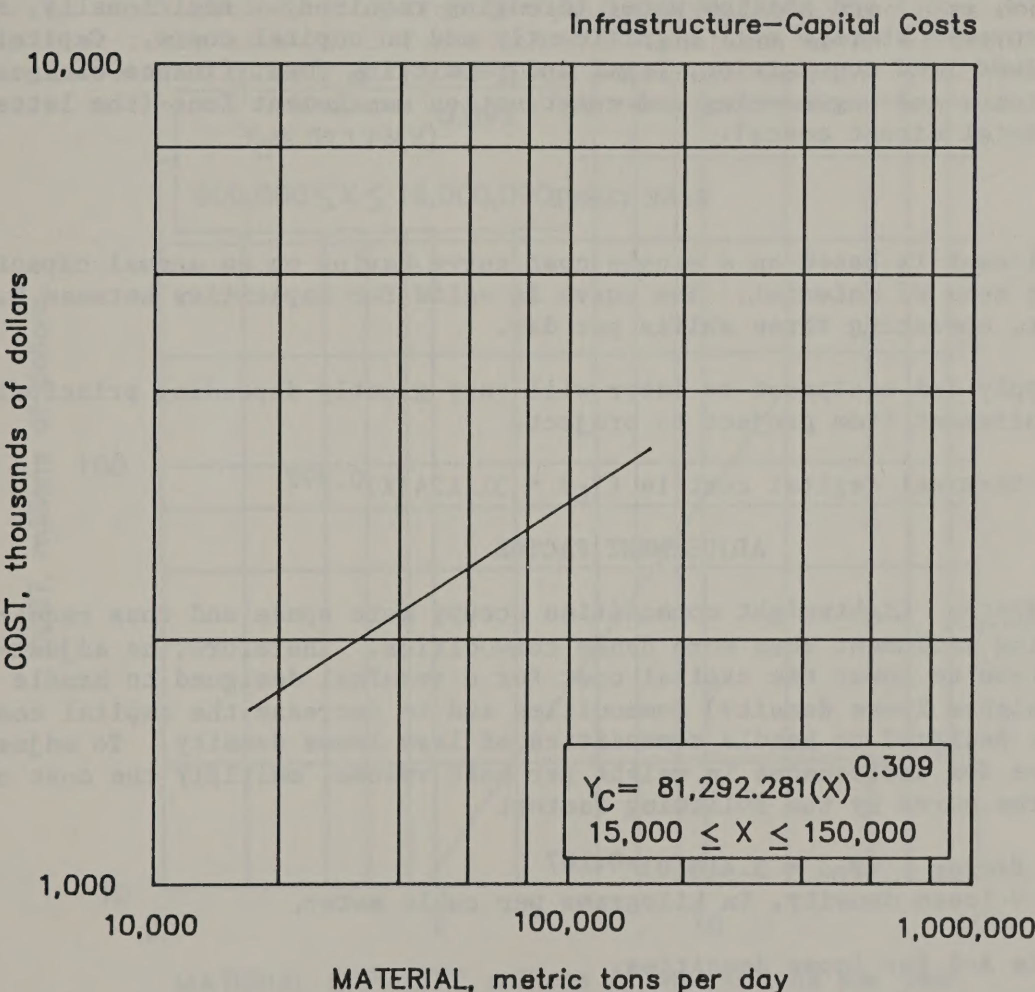
$$\text{Conveyor length and slope factor} \quad (F_L) = [0.917+0.00940(S)][L/1]$$

where L = length, in kilometers
and S = slope, in degrees, between 0^o and 15^o.

The cost for a decline conveyor is equal to that for a horizontal conveyor (0^o slope).

Stacker-Tripper Factor If the material is conveyed to a processing plant or other end point such as a port facility, the capital cost for unloading from the conveyor is included in those sections. If the material is waste rock, then the cost for a tripper or stacker should be added to the estimated capital cost. Costs for these items vary greatly but can range from $600,000 for a stacker or tripper that handles 15,000 mtpd waste material to $5,000,000 for a stacker or tripper that handles 150,000 mtpd of waste rock.

Belt Life The conveyor belt, 36% of equipment cost, has an average wear life of 8 to 10 yr of use, based on three shifts per day, 350 operating days per year, and depending on the abrasiveness of the material. The total replacement of the belt is standard procedure after excessive wear.



8.1.4.5. Long distance surface conveyor

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.4. TRANSPORTATION

8.1.4.7. MARINE TERMINAL

The curve applies to costs for a deep-water, export, bulk ore marine terminal. Costs include basic operations of rail or barge receiving, storage (open), reclaiming, and ship-loading. Ore storage, with capability to mix different ore grades, has a capacity of 10% of annual throughput. It is assumed that soil conditions are good. Significant additional costs will be incurred under conditions of poor site soil (e.g., swamps, etc.) and shallow water (dredging required). Additionally, a requirement for covered storage will significantly add to capital costs. Capital costs do not include land acquisition, legal and permitting fees, finance charges, off-site alterations, and engineering and construction management fees (the latter, typically 8% of total direct costs).

BASE CURVE

The total capital cost is based on a single cost curve having on an annual capacity of (X), in metric tons of material. The curve is valid for capacities between 0.9 and 16 million mt, operating three shifts per day.

The ratios of supply and equipment to labor will vary greatly depending principally on the civil requirement from project to project.

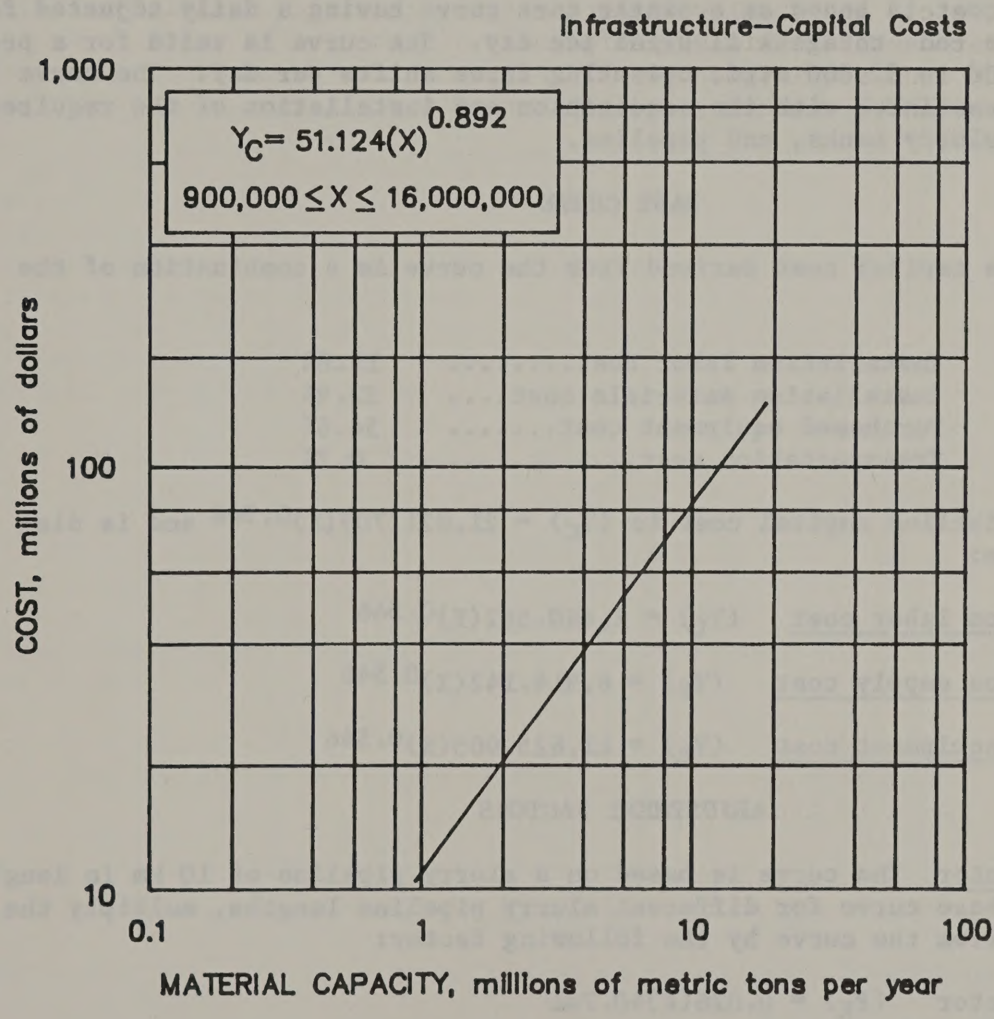
The total marine terminal capital cost is $(Y_C) = 51.124(X)^{0.892}$

ADJUSTMENT FACTOR

Density (Loose) Factor Lightweight commodities occupy more space and thus require larger handling equipment than more dense commodities. Therefore, an adjustment is required to lower the capital cost for a terminal designed to handle more dense (higher loose density) commodities and to increase the capital cost of a terminal designed to handle commodities of less loose density. To adjust the base curve for differences in weight per unit volume, multiply the cost obtained from the curve by the following factor:

Density factor $(F_D) = 3.418(D)^{-0.167}$
where D = loose density, in kilograms per cubic meter.

See table A-2 for loose densities.



8.1.4.7. Marine terminal

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.4. TRANSPORTATION

8.1.4.8. SLURRY PIPELINE

The capital cost curve for the slurry pipeline is for the acquisition and installation of equipment for pumping a slurry 10 km at a lift of 150 m with a specific gravity of the solids of 4.3. The slurry pipeline circuit includes slurry storage tanks, booster and high-pressure slurry pumps, and the pipeline.

The total capital cost is based on a single cost curve having a daily adjusted feed rate (X), in metric tons material slurried per day. The curve is valid for a production range of 900 to 32,000 mtpd, operating three shifts per day. The curve includes all costs associated with the acquisition and installation of the required pumps, agitators, slurry tanks, and pipeline.

BASE CURVE

The slurry pipeline capital cost derived from the curve is a combination of the following costs:

Installation labor cost........	11.8%
Installation materials cost....	32.9%
Purchased equipment cost.......	54.6%
Transportation cost............	0.7%

The total slurry pipeline capital cost is $(Y_C) = 21{,}021.709(X)^{0.546}$ and is distributed as follows:

(L) Construction labor cost $(Y_L) = 2{,}480.562(X)^{0.546}$

(S) Construction supply cost $(Y_S) = 6{,}916.142(X)^{0.546}$

(E) Purchased equipment cost $(Y_E) = 11{,}625.005(X)^{0.546}$

ADJUSTMENT FACTORS

Pipeline Length Factor The curve is based on a slurry pipeline of 10 km in length. To adjust the base curve for different slurry pipeline lengths, multiply the cost obtained from the curve by the following factor:

Length factor $(F_K) = 0.026(K)+0.741$
where K = length, in kilometers.

See table A-3 for average pipeline lengths.

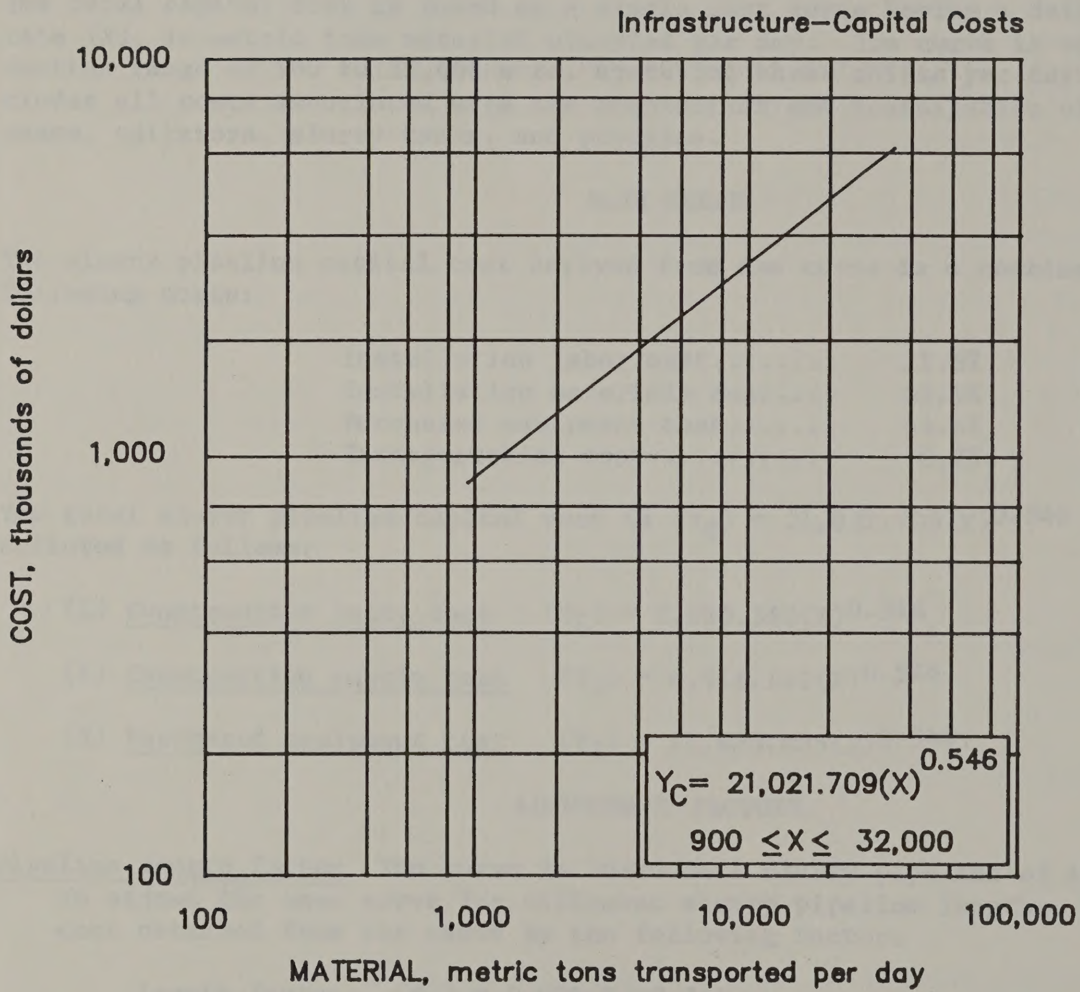
Slurry Pipeline Lift Factor The base curve was calculated for a slurry pipeline with a lift of 150 m. To adjust the base curve for a different lift, multiply the cost obtained from the curve by the following factor:

Lift factor $(F_L) = 0.0009(L)+0.871$
where L = length, in meters.

<u>Specific Gravity Factor</u> The base curve was calculated for a slurry pipeline pumping solids with specific gravity (S.G.) of 4.3. To adjust the curve for a different specific gravity, multiply the cost obtained from the curve by the following factor:

Specific gravity factor $(F_S) = 0.023(S)+0.903$
where S = new specific gravity.

See table A-3 for average specific gravities.



8.1.4.8. Slurry pipeline

8.1.5. TOWNSITE

The following housing costs are for a typical average quality park based on using trailers or manufactured mobile home housing containing between 150 and 200 units. Costs are quoted per individual housing unit. Costs are factored by using the Bureau of Labor Statistics Industrial Materials Cost Index. Site costs do not include land site acquisition, construction of utility trunk lines to the site, or a wastewater treatment plant. Wastewater disposal uses a septic tank and drain field; however, transportation and setup costs to areas within 100 miles of Denver, CO, are included.

TYPICAL AVERAGE SITE COSTS FOR FAMILY OR BACHELOR UNIT

	Family	Bachelor
Site preparation (typical avg. area 410 m^2).............	\$1,050	\$320
Streets (7.9- to 9.8-m wide, 7.6-cm asphalt or 7.5-cm gravel edged or curbed)..................................	810	270
Patios and walks...	610	200
Septic tank, includes drain field.......................	1,360	750
Water, connected to unit................................	550	550
Gas, low-pressure, connected............................	310	310
Electrical, 80- to 150-A connected service to each unit..	890	890
Office, recreation, laundry.............................	1,250	1,250
Total..	6,830	4,540

The following adjustment factors should be applied to the total typical 'average' site cost where either quality or quantity differs.

Site preparation adjustment multipliers to total typical average'site cost are as follows:

Description	Quality factor	Quantity	Factor
Low quality (300 m^2/space)	0.70	40- 80	1.07
		80-125	1.00
	150-250	0.92	
Average (410 m^2/space)	1.00	50-125	1.10
		150-200	1.00
		250-300	0.95
Good (520 m^2/space)	1.30	50-150	1.10
		175-200	1.00
		250-350	0.97

In addition, the following accessories may also be required:

Skirting at base of trailer....................	$620.00
Landing and steps..............................	360.00
Canopies over landings.........................	550.00
Air conditioning--using existing heater.......	840.00

HOUSING UNITS

Family Units--With living, dining, kitchen, bath, and sleeping facilities for two adults and two to four children. Cost is for typical average quality.

Single-wide (4.27m by 19.50m)............	$15,400
Double-wide (7.31m by 14.63m)............	$26,400

Quality adjustments to the single-wide, double-wide basic costs are made by multiplying the above housing unit average quality costs by the following factors:

Low quality	
Single-wide......	1.12
Double-wide......	1.16
Average	
Single-wide......	0.90
Double-wide......	0.87
Excellent quality	
Single-wide......	1.25
Double-wide......	1.34

Quantity adjustments--For quantities greater than 10 units, decrease overall costs by 10%.

Snowload adjustment--For areas of heavy snowfall, increase basic unit costs 5% for increased roof support design.

Bachelor Units--Consisting of single person motel-style rooms with a kitchen and dining room. Rooms share a centrally located restroom and shower facility. Cost is for typical average quality.

Bachelor Unit..................................	$15,000

Number of persons adjustment--Per person cost is based on housing 400 personnel. Lodging capital costs for greater than 500 people, decrease costs by 10%. Increase costs by 15% for less than 300 and 20% for less than 200.

PRIMARY UTILITIES

Electrical, cost per linear meter:

Main overhead electric powerlines............	$26.32/linear m
Lateral overhead lines.........................	$ 8.25/linear m

<u>Water</u>

Main, 15.24 cm plastic (add or deduct $5.75 per 2.54-cm diam.).....................	$35.80/linear m
Lateral, 2.54 cm...............................	$17.22/linear m

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.6. WASTEWATER TREATMENT

8.1.6.1. CLARIFICATION

Clarification capital cost is for the acquisition and installation of equipment for water clarification and softening by precipitation and/or coagulation. The all metal solids-contact clarifier combines into one operation--quick mixing, flocculation, clarification, and sludge thickening. The unit will selectively or simultaneously remove turbidity, color, organic matter, manganese, iron, hardness, alkalinity, taste, and odor. The cost curve is based on clarifiers ranging in diameter from 2.74 m to 45.72 m (cross-sectional area ranging from 5.9 to 1,642 m^2).

BASE CURVES

Total cost is based on a single cost curve having a tank diameter of (X) in meters. The curve includes all costs associated with acquisition and installation of concrete pad, clarifier structure, and control-monitor equipment for sludge level and sludge density control.

The total clarification capital cost derived from the curve is a combination of the following costs:

Construction labor cost......	19%
Construction supply cost.....	5%
Purchased equipment cost.....	76%

The total clarification capital cost is $(Y_C) = 15,631.070(X)^{0.991}$ and is distributed as follows:

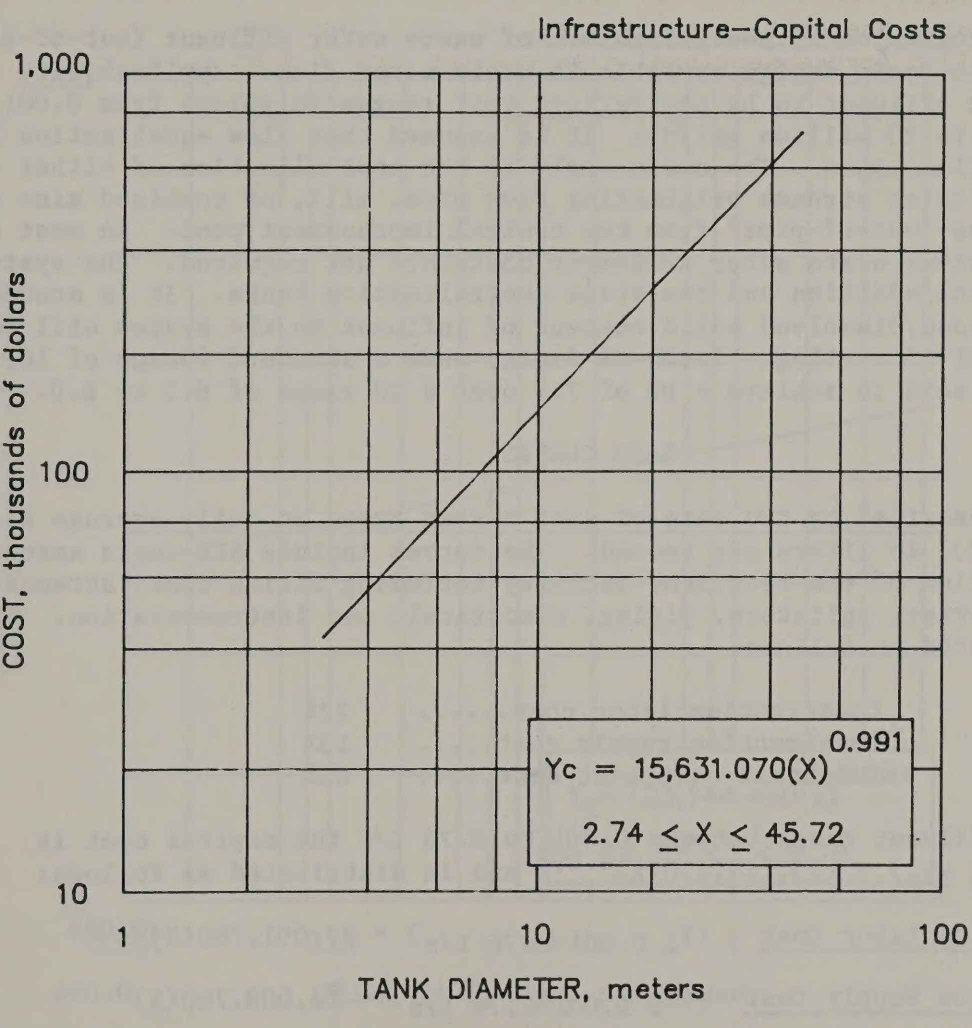
(L) <u>Construction Labor Cost</u> $(Y_L) = 2,969.910(X)^{0.991}$

(S) <u>Construction Supply Cost</u> $(Y_S) = 781.550(X)^{0.991}$

(E) <u>Purchased Equipment Cost</u> $(Y_E) = 11,879.610(X)^{0.991}$

Note--Sizing, of clarifier is based on one principal parameter--'rise rate', the vertical velocity of the stream through the clarifier. If the diameter or cross-sectional area of the clarifier is unknown, and the feed flow rate is known and the rise rate is assumed to be 0.015 m/min, then the diameter (D), or equivalent cross-sectional area, of the clarifier can be estimated with the equation:

Clarifier diameter $(D) = 1.128[(Q)/(R)]^{0.500}$
where R = rise rate, in meters per minute,
and Q = design flow rate, in cubic meters per minute.



8.1.6.1. Wastewater treatment
CLARIFICATION

8.1. INFRASTRUCTURE--CAPITAL COSTS

8.1.6. WASTE WATER TREATMENT

8.1.6.2. NEUTRALIZATION

The Environmental Protection Agency's publication EPA-600/2-82-00/d "Treatability Manual, Vol. IV, Cost Estimating," April 1983, was the source of cost development. One is referred to this manual if further detail in neutralization costs is needed. Additionally, other waste water treatment methods are costed in this EPA manual.

The capital cost curves cover neutralization of waste water effluent (out-of-pipe) when required. The basic design variable is waste water flow. Applicability of the curves are for effluent to be neutralized that ranges in volume from 0.001 to 876 L/s (22.8 gal to 20 million gal/d). It is assumed that flow equalization is provided by a tailings pond. The costs apply to the neutralization of either acidic or basic waste water streams originating from mine, mill, or combined mine and mill after it flows 'out-of-pipe' from the central impoundment pond. In most mining operations further waste water treatment costs are not required. The system consists of chemical addition and two-stage neutralization tanks. It is assumed that pH and suspended/dissolved solid content of influent to the system will be unknown at this level of costing. Basis of design uses a standard dosage of 100 mg/L lime and 100 mg/L acid to achieve a pH of 7.0 over a pH range of 6.5 to 8.0.

BASE CURVES

Total costs are described by two sets of cost curves based on daily average waste water flow rate (X), in liters per second. The curves include all costs associated with the construction of the treatment facility including mixing tank, attenuation tank, chemical storage, agitators, piping, electrical, and instrumentation. These costs are distributed as follows:

Construction labor cost......	22%
Construction supply cost.....	13%
Purchased equipment cost.....	65%

For waste water effluent rates between 0.001 to 8.76 L/s the capital cost is $(Y_{C\ 0.001\text{-}8.76\ L/s}) = 123{,}144.490(X)^{0.094}$ and is distributed as follows:

(L) Construction Labor Cost $(Y_{L\ 0.001\text{-}8.76\ L/s}) = 27{,}091.780(X)^{0.094}$

(S) Construction Supply Cost $(Y_{S\ 0.001\text{-}8.76\ L/s}) = 16{,}008.780(X)^{0.094}$

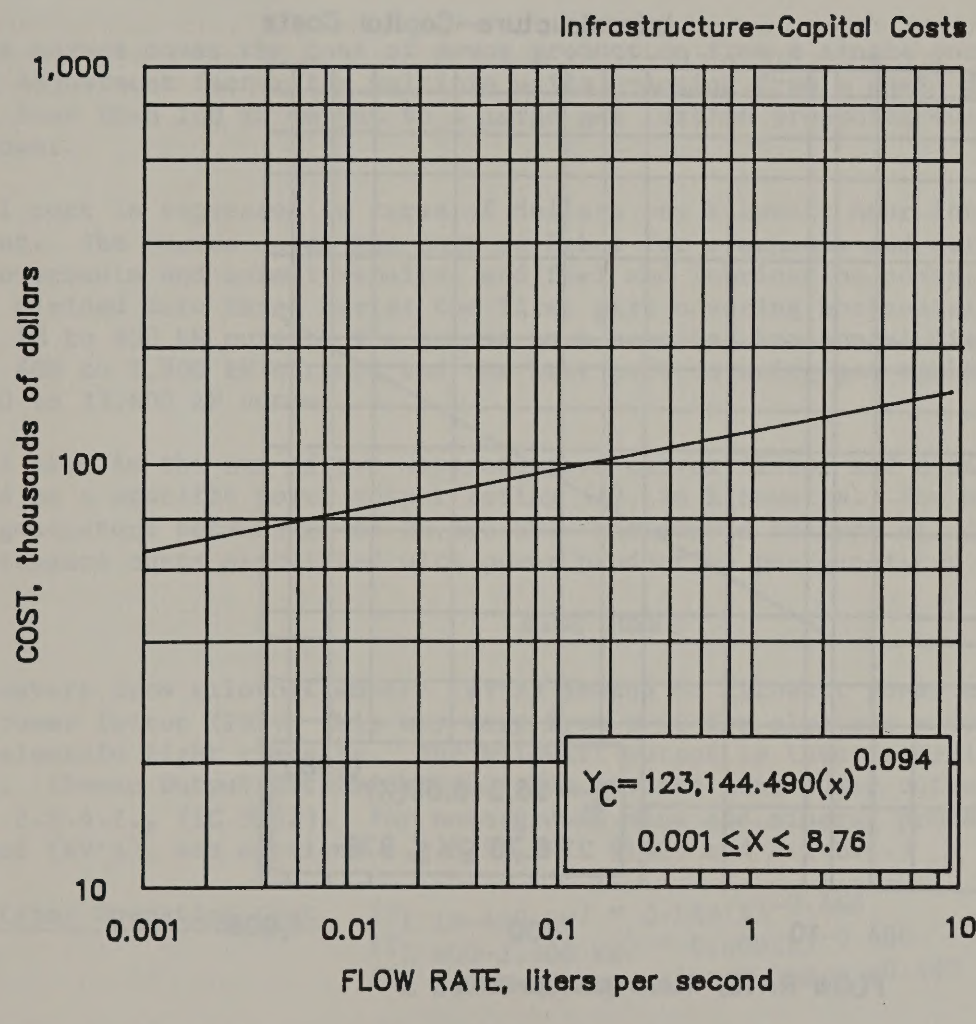
(E) Purchased Equipment Cost $(Y_{E\ 0.001\text{-}8.76\ L/s}) = 80{,}043.930(X)^{0.094}$

For waste water effluent rates between 8.76 to 876 L/s the capital cost is $(Y_C\ 8.76\text{-}876\ L/s) = 26{,}346.39(X)^{0.562}$ and is distributed as follows:

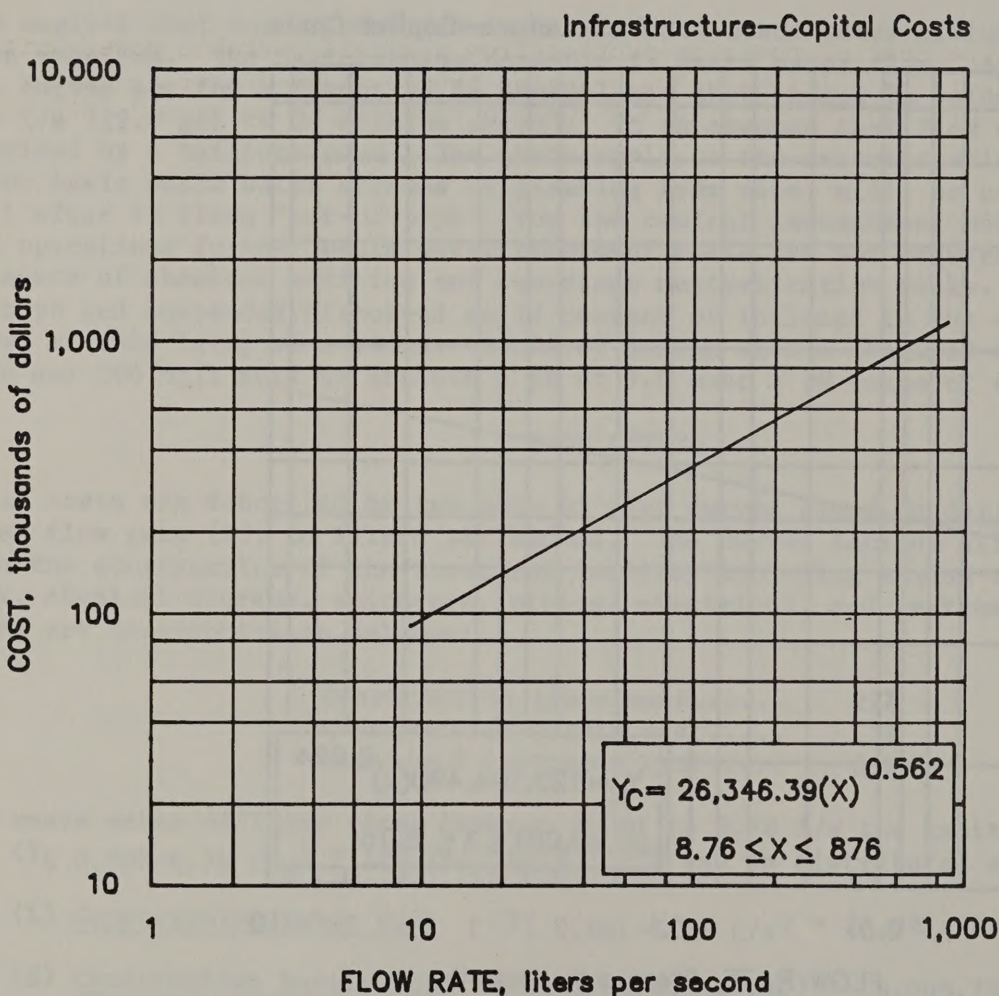
(L) Construction Labor Cost $(Y_L\ 8.76\text{-}876\ L/s) = 5{,}796.21(X)^{0.562}$

(S) Construction Supply Cost $(Y_S\ 8.76\text{-}876\ L/s) = 3{,}425.03(X)^{0.562}$

(E) Purchased Equipment Cost $(Y_E\ 8.76\text{-}876\ L/s) = 17{,}125.15(X)^{0.562}$



8.1.6.2.a Wastewater treatment
NEUTRALIZATION



8.1.6.2.b Wastewater treatment
NEUTRALIZATION

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.2. GENERAL OPERATIONS

9.1.2.2. PORTABLE POWER GENERATION

This section is to be used in conjunction with section 8.1.2.2. when electrical power is unavailable through a commercial power utility company or when it would be uneconomical to run power distribution facilities to the user. The total cost per kilowatt hour replaces the commercial Denver, CO, power rate used in other sections of this manual.

These curves cover the cost of power production from a single portable power unit (see adjustment factor for multiple units) ranging from a small diesel generator with less than 100 kW output to a large gas turbine producing more than 20,000 kW of power.

Total cost is expressed in terms of dollars per kilowatt hour for a specific power output. The curves cover the cost of labor for overhauls and normal repairs, parts for overhauls and normal repairs, and fuel and lubrication costs. The curves have been divided into three parts: the first part covering horizontal diesel generators from 18 to 400 kW output, the second part covering horizontal diesel generators from 400 to 2,900 kW output, and the last part covering gas turbine generators from 2,900 to 23,600 kW output.

Total cost is the sum of two separate cost curves (labor and equipment operation) based on a specific power output rating (X), in kilowatts. The curves are valid for generators between 18 to 23,600 kW. The curves include all daily operating and maintenance costs associated with power production per generator unit.

BASE CURVE

To convert from kilovolt ampere (kV•A) demand to kilowatt power output estimate the power factor (PF). This may vary from 0.80 for electric motor circuits to 1.00 for electric light circuits. The kilowatt output is then determined by kV•A x PF = kW. (Power Output Determination - for surface mine power output (kW), see section 2.2.4.2., (IC 9142). For underground mine and mineral processing plant power demand (kV•A), see sections 4.2.5.3., (IC 9142) and 6.1.8.4.)

(L) Labor Operating Cost $(Y_{L\ 18\text{-}400\ kW}) = 0.169(X)^{-0.466}$
$(Y_{L\ 400\text{-}2,900\ kW}) = 0.409(X)^{-0.480}$
$(Y_{L\ 2,900\text{-}23,600\ kW}) = 0.008(X)^{-0.445}$

The operating labor costs are distributed as follows:

Direct labor...............	0%
Maintenance labor..........	100%

The labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Mechanics................	100%	$18.11

The average wage for labor is $18.11 per worker-hour (including burden and average shift differential).

The labor curves do not contain any operating labor costs since all units operate unattended in an automatic mode (some smaller units may not have automatic starting systems and would require a manual start). The only labor necessary is that which is required for maintenance and scheduled overhauls by mechanics.

(E) Equipment Operation Costs $(Y_E\ 18\text{-}400\ kW) = 0.145(X)^{-0.075}$
$(Y_E\ 400\text{-}2{,}900\ kW) = 0.158(X)^{-0.070}$
$(Y_E\ 2{,}900\text{-}23{,}600\ kW) = 0.131(X)^{-0.122}$

The general equipment operating cost component distribution is as follows:

	Repair parts	Fuel and lube	Tires
Horizontal diesel:			
18-400 kW	18.0%	73%	9%
400-2,900 kW	12.0%	79%	9%
Gas turbine:			
2,900-23,600 kW	11%	75%	14%

The parts category includes normal maintenance parts such as belts and pumps, and major overhaul items such as valves, injectors, brushes, and commutators. The fueling cost is based on $1.00/gal diesel fuel (at 7.093 lb/gal) or $3.20/1,000 ft^3 of natural gas with a Btu rating of 1,050 Btu/ft^3.

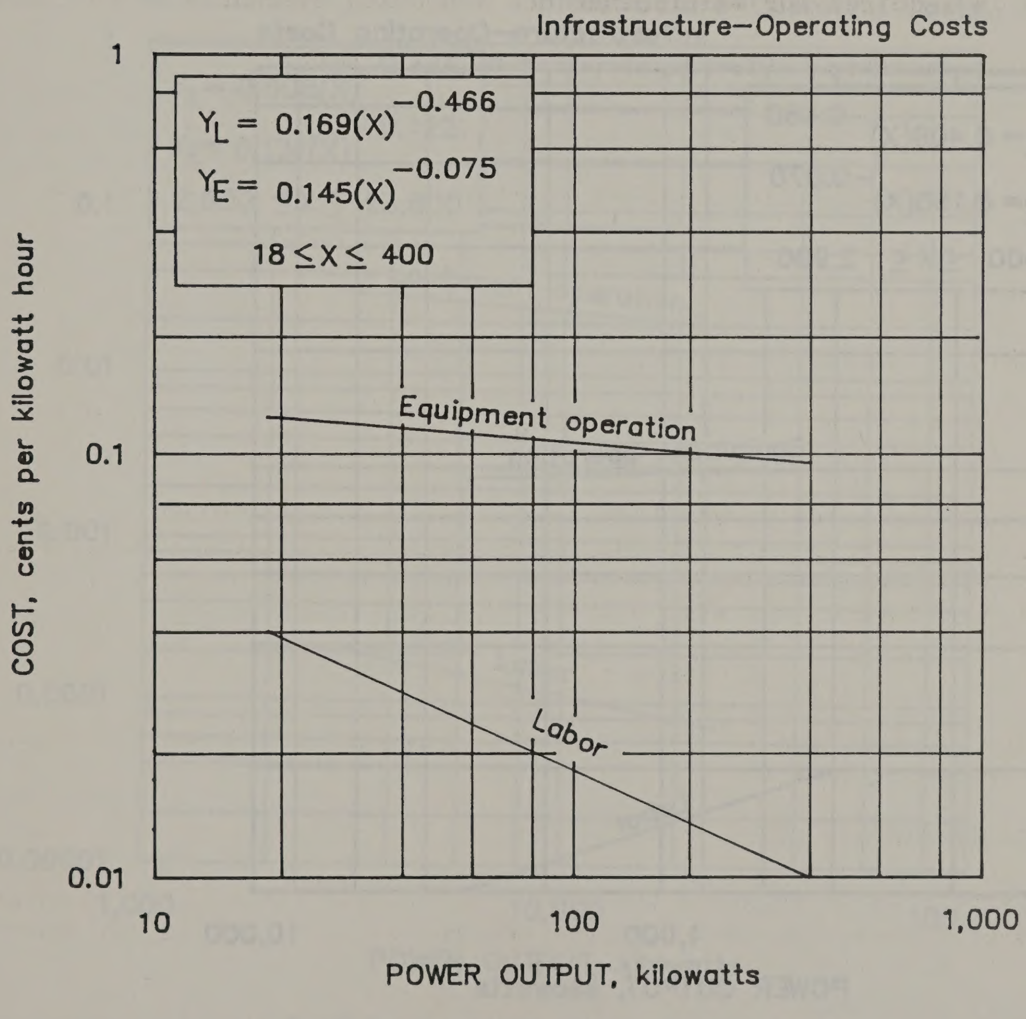
ADJUSTMENT FACTORS

Sulfur Fuels Factor If high sulfur fuels are used, multiply the labor and parts costs by the following factor:

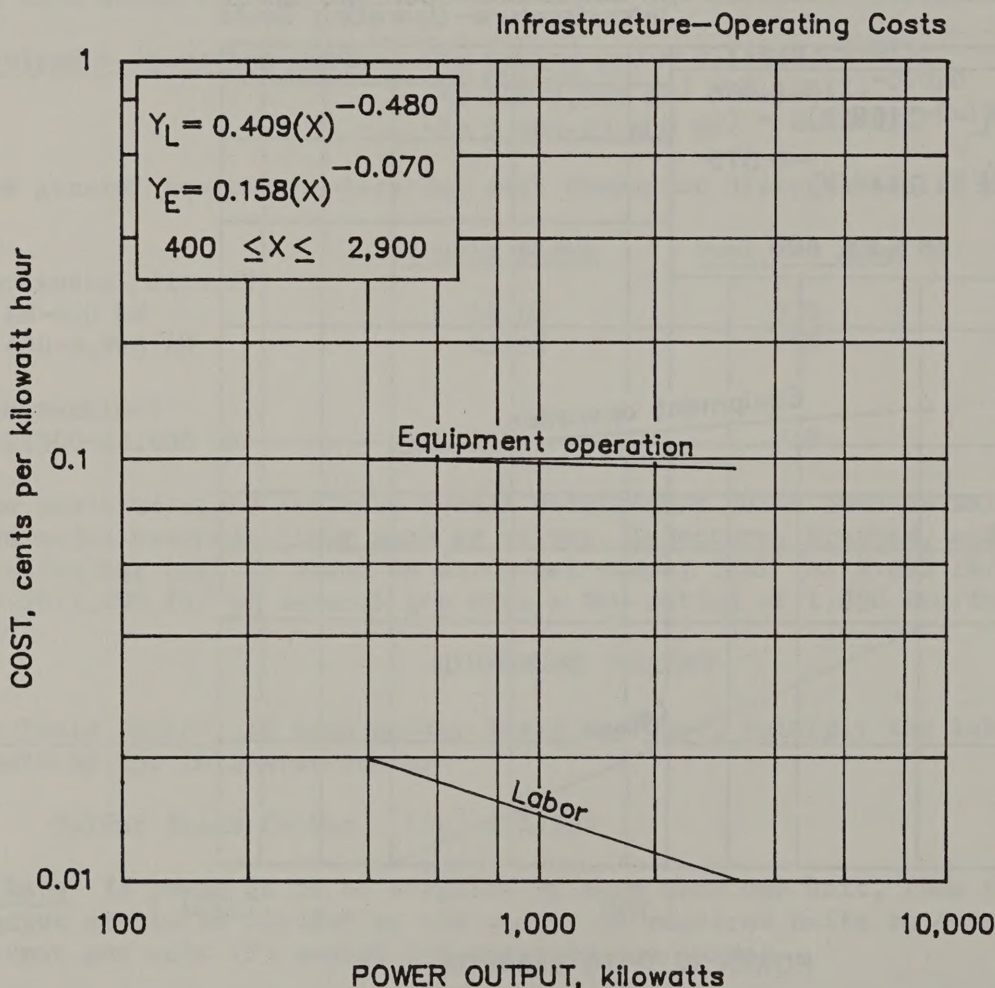
Sulfur fuels factor $(F_L) = 1.333$

Power Rate If power is to be supplied by more than one unit, then the total power output should be divided by the number of required units to obtain the power output per unit (X) needed for entering the curves.

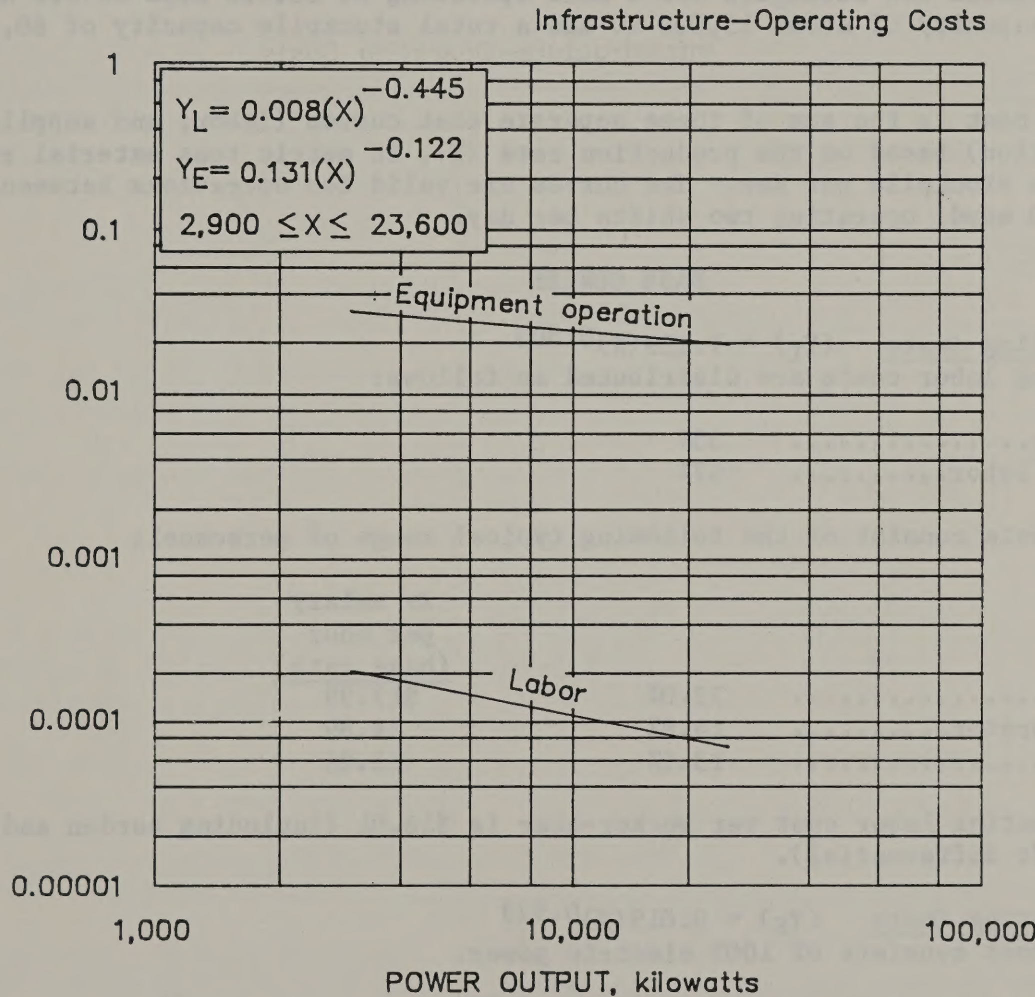
Power Source For those cases where power is supplied to the mine and mineral processing plant from different sources as a result of geographic or economic constraints, separate cost estimates, using this section, must be made to reflect the independent power outputs. This will result in different power costs for mines and mineral processing plants and must be accounted for separately in the mining and mineral processing sections of this manual.



9.1.2.2.a Portable power generation



9.1.2.2.b Portable power generation



9.1.2.2.c Portable power generation

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.2. GENERAL OPERATIONS

9.1.2.3. STOCKPILE STORAGE FACILITIES

Stockpile operating costs, as determined in this section, are based on metric tons of stockpiled material reclaimed during a two-shift-per-day operation. The costs represented are only applicable for stockpiles formed and reclaimed by conveyors. The daily reclaim rate is typically about 67% of the stockpile's live storage capacity. Total stockpile capacity is normally about 600% of the daily reclaim rate. For example, a coarse ore stockpile for a mill operating at 10,000 mtpd of ore has a live storage capacity of about 15,000 mt and a total stockpile capacity of 60,000 mt.

Total operating cost is the sum of three separate cost curves (labor, and supplies, equipment operation) based on the production rate (X), in metric tons material reclaimed from the stockpile per day. The curves are valid for operations between 2,000 to 200,000 mtpd, operating two shifts per day.

BASE CURVES

(L) Labor Operating Costs $(Y_L) = 7.229(X)^{0.503}$
The operating labor costs are distributed as follows:

Direct labor...............	33%
Maintenance labor..........	67%

The labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Mechanic...................	72.0%	\$17.99
Conveyor operator..........	14.8%	14.89
Laborer....................	13.2%	13.26

Average operating labor cost per worker-hour is \$16.91 (including burden and average shift differential).

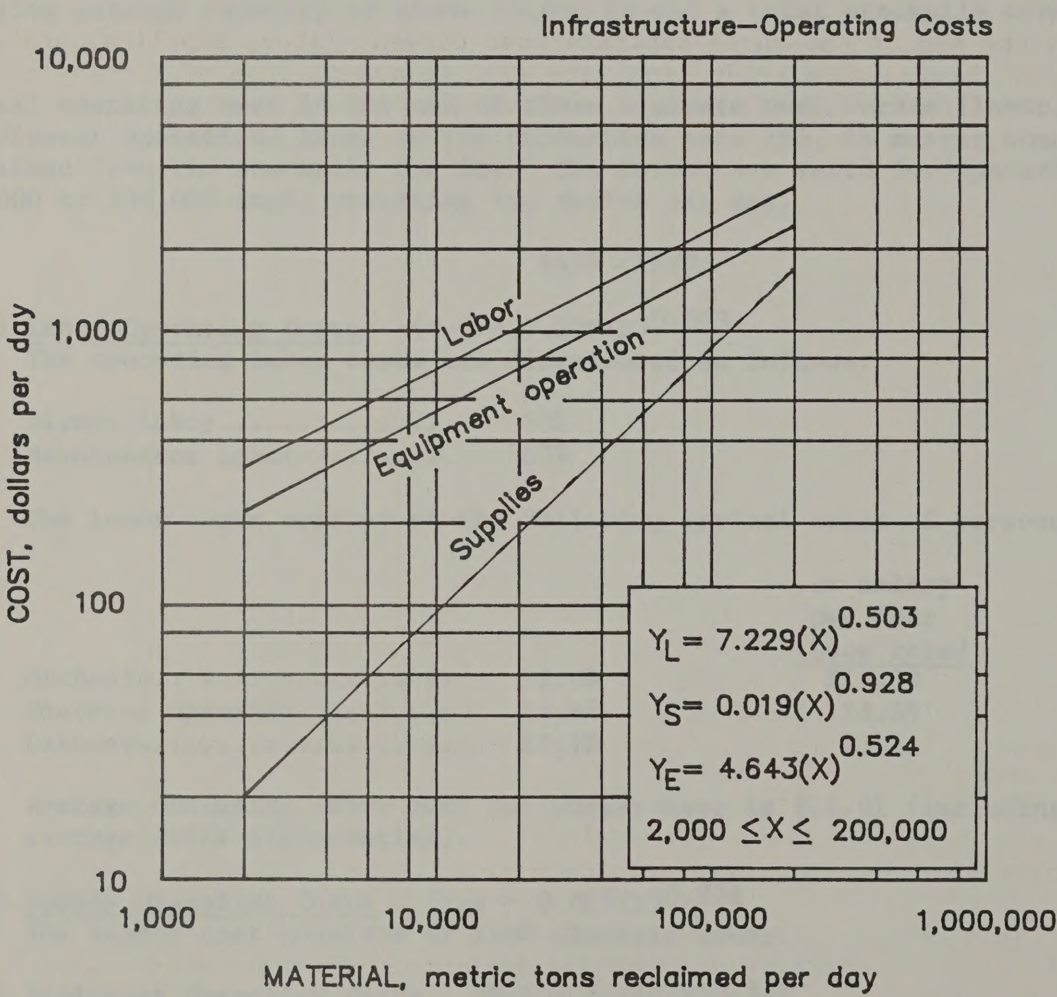
(S) Supply Operating Costs $(Y_S) = 0.019(X)^{0.928}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Costs $(Y_E) = 4.643(X)^{0.524}$
The equipment operating cost consists of 94% for repair and maintenance parts and 6% for lubrication.

ADJUSTMENT FACTORS

Shift-Reclaim Rate If a stockpile facility is operated one shift per day, multiply the daily reclaim rate by two; calculate the operating costs from the base curves using the adjusted reclaim rate; then decrease the calculated cost by 50% to arrive at the adjusted cost. If the facility is operated three shifts

per day, multiply the daily reclaim rate by 0.67; calculate the operating costs from the base curves using the adjusted reclaim rate; then increase the calculated cost by 50% to arrive at the adjusted cost.



9.1.2.3. Stockpile storage facilities

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.3. LOADING FACILITIES

9.1.3.1. LOAD-OUT FACILITIES

The load-out operating costs represented are only applicable for concentrates stored using a conveyor, bucket elevator, and elevated storage bin system. The storage bins are capable of holding a 2-day supply of mill concentrate output, and are emptied every other day into 45 mt trucks or 90 mt railcars for delivery to the smelter. An example of the type of materials stored would be copper or molybdenum concentrates.

The total cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) having on a production rate (X), in metric tons of concentrate transferred from a mill to storage bins in a 24 h period. The curves are valid for operations between 150 and 1,500 mtpd, operating one shift per day.

BASE CURVES

(L) Labor Operating Costs $(Y_L) = 71.565(X)^{0.145}$
The operating labor costs are distributed as follows:

Direct labor...............	84%
Maintenance labor..........	16%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Mechanic..................	42.9%	$17.99
Conveyor Operator.........	30.2%	14.89
Laborer...................	26.9%	13.26

The average wage for labor is $15.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Costs $(Y_S) = 0.0009(X)^{1.202}$
The supply curve consists of 100% electric power.

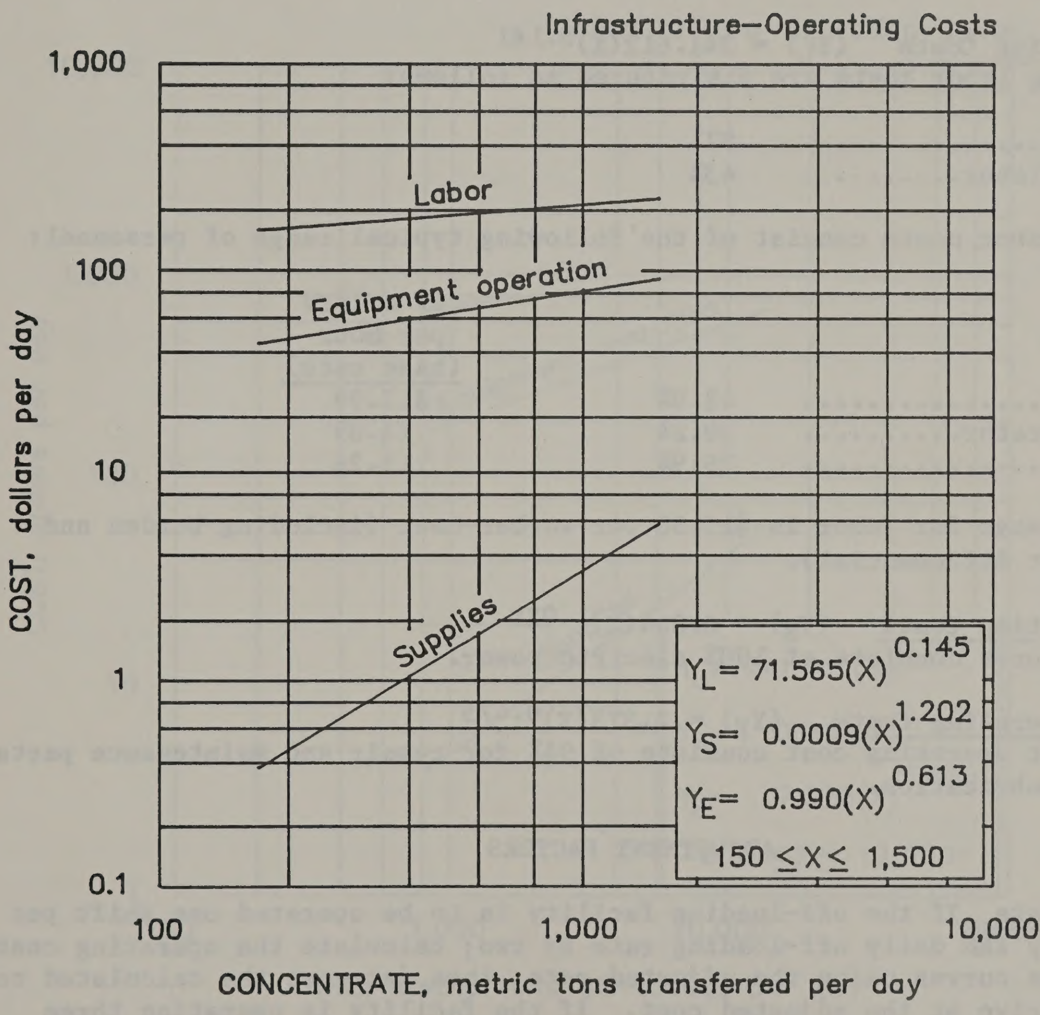
(E) Equipment Operating Costs $(Y_E) = 0.990(X)^{0.613}$
The equipment operating cost consists of 94% for repair and maintenance parts and 6% for lubrication.

ADJUSTMENT FACTORS

Secondary Mineral Recovery Operating costs for the recovery of secondary minerals are not included in this section. If such operations are considered, appropriate adjustments should be made to the cost curves.

Shift factor Planned use of off-loading equipment is considered to occur intermittently throughout the 24-h work day as concentrates in adequate quantities are

made available from the mill for transportation to the storage bins. If the operations occur for periods of time 110% greater than or 70% less than 9 h/d, suitable adjustments must be made to the cost curves.



9.1.3.1. Loading facilities
LOAD-OUT FACILITIES

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.3. LOADING FACILITIES

9.1.3.2. OFF-LOADING FACILITIES

The total cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) having on a production rate (X), in metric tons of ore off-loaded and stored in bins for use by the mill per day. The curves are valid for operations between 800 and 12,000 mtpd, operating two shifts per day.

BASE CURVES

(L) Labor Operating Costs $(Y_L) = 241.612(X)^{0.161}$
The operating labor costs are distributed as follows:

Direct labor...............	57%
Maintenance labor..........	43%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Mechanic....................	42.9%	$17.99
Conveyor Operator..........	30.2%	14.89
Laborer....................	26.9%	13.26

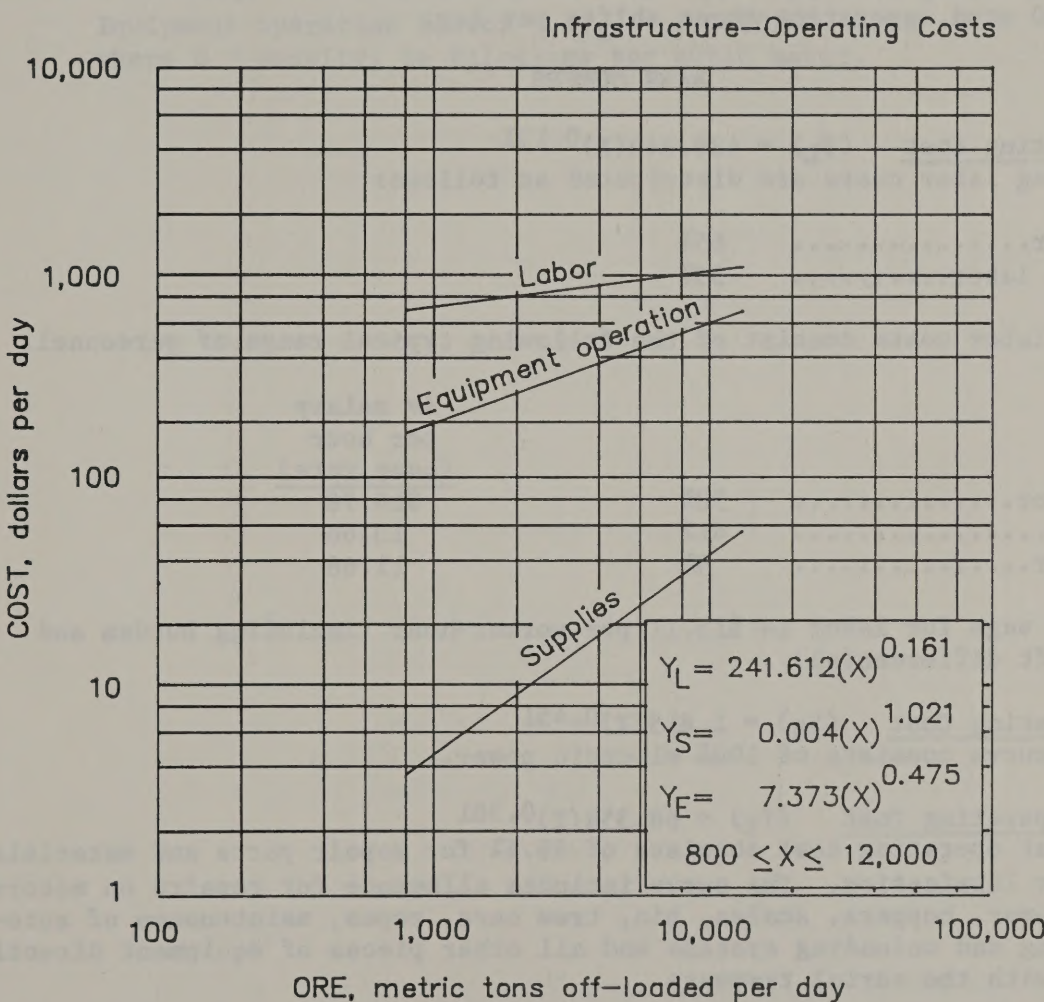
The average wage for labor is $15.38 per worker-hour (including burden and average shift differential).

(S) Supply Operating Costs $(Y_S) = 0.004(X)^{1.021}$
The supply curve consists of 100% electric power.

(E) Equipment Operating Costs $(Y_E) = 7.373(X)^{0.475}$
The equipment operating cost consists of 94% for repair and maintenance parts and 6% for lubrication.

ADJUSTMENT FACTORS

Variable shift rate If the off-loading facility is to be operated one shift per day, multiply the daily off-loading rate by two; calculate the operating costs from the base curves using the adjusted rate, then decrease the calculated cost by 50% to arrive at the adjusted cost. If the facility is operating three shifts per day, multiply the daily off-loading rate by 0.67; calculate the operating costs from the base curves using the adjusted off-loading rate, then increase the calculated cost by 50% to arrive at the adjusted cost.



9.1.3.2. Loading facilities
OFF—LOADING FACILITIES

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.4. TRANSPORTATION

9.1.4.1. AERIAL TRAMWAY

The operating cost curves for aerial tramways cover the cost for tramming ore or waste material. The base curves are based on an aerial tramway of 3.0 km in length with a slope of 15°. The bulk density of trammed material is 1442.5 kg/m^3 (92.0 lb/ft^3). The total cost is the sum of the three separate cost curves (labor, supplies and equipment operation) based on a production rate (X), in metric tons of material transported per day. The curves are valid for operations between 2,040 and 13,800 mtpd, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 439.940(X)^{0.121}$
The operating labor costs are distributed as follows:

Direct labor...............	65%
Maintenance labor..........	35%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Tram Operator..............	50%	$16.78
Tram Helper................	41%	13.66
Tram Laborer...............	9%	11.68

The average wage for labor is $15.11 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.815(X)^{0.451}$
The supply curve consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 68.358(X)^{0.381}$
The equipment operating cost consists of 99.4% for repair parts and materials and 0.6% for lubrication. The curve includes allowance for repairs on motors, feeder conveyor, hoppers, scales, bin, tram cars, ropes, maintenance of automatic loading and unloading systems and all other pieces of equipment directly associated with the aerial tramways.

ADJUSTMENT FACTORS

Aerial Tramway Length Factor The base curve is calculated for a tramway 3 km in slope length. To adjust the base curve for a different aerial tramway slope length, multiply the costs obtained from the base curves by the following factors:

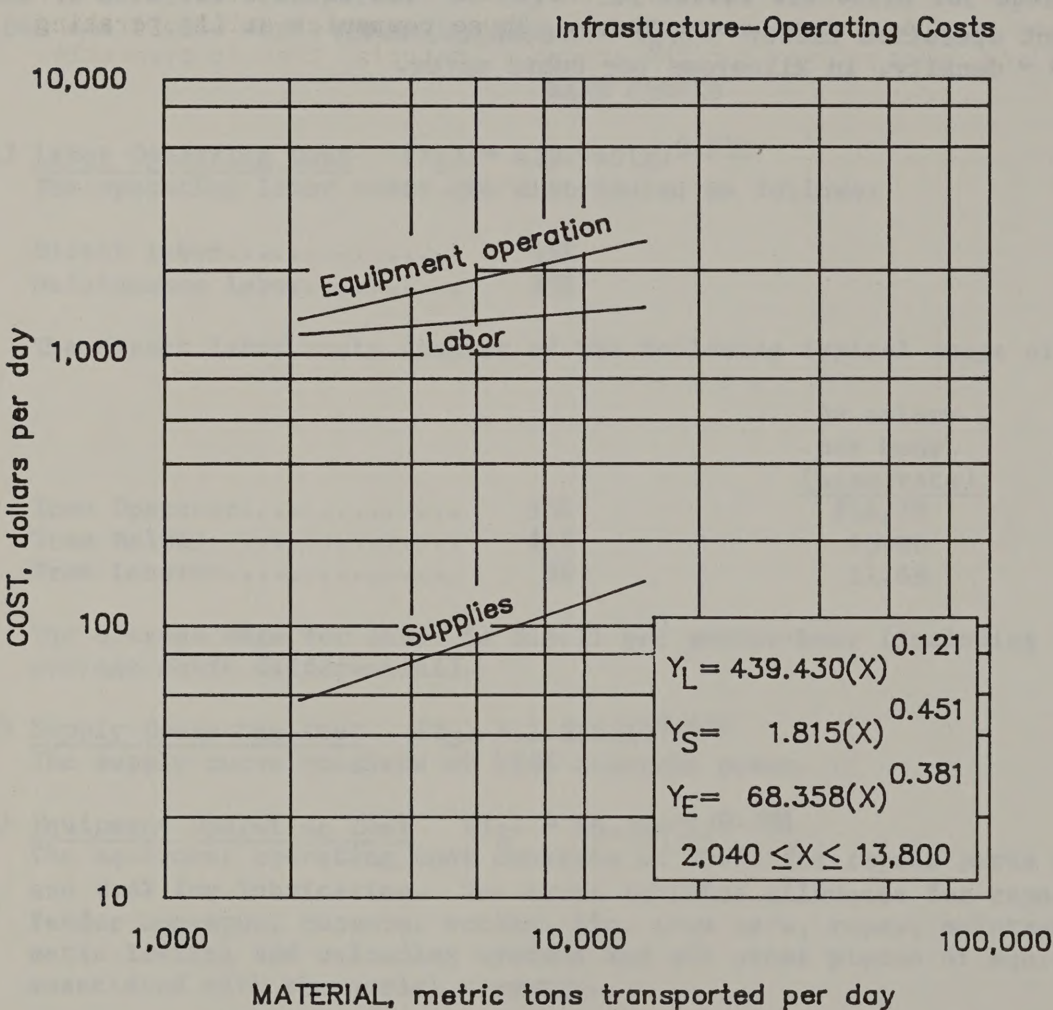
Labor factor $(F_L) = 0.113(L)+0.660$

Supply factor $(F_S) = 0.157(L)+0.528$

Equipment operation factor $(F_E) = 0.226(L)+0.321$
where:
L = slope length, in kilometers.

<u>Bulk Density Factor</u> The base curve was based on a material trammed bulk density of 1,442.5 kg/m^3 (92.0 lb/ft^3). To adjust the base curve for a different material bulk density, multiply the costs obtained from the equipment operation curve by the following factor:

Equipment operation factor $(F_E) = 0.00003(D)+0.957$
where D = density, in kilograms per cubic meter.



9.1.4.1. Aerial tramway

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.4. TRANSPORTATION

9.1.4.3. LONG-DISTANCE BARGE HAULAGE

Shipping large tonnage commodities by barge can be an effective method of transportation if access points are available and high speed is not important. It is even possible to ship mineral materials a short distance by rail and then transfer the material to barge and still save money over rail haulage alone.

With the deregulation of the barge industry, there has been an increase in competition and a decrease in the number of operators. Those companies still operating have found themselves overequipped for the amount of material that is presently being hauled.

As of January, 1984, typical costs for transportation of bulk cargoes have been between \$0.0027 and \$0.0030/mt km, with the average cost being near \$0.0028/mt km.

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.4. TRANSPORTATION

9.1.4.4. LONG-DISTANCE RAIL HAULAGE

The following tabulation gives the average cost, in cents per metric ton-kilometer, for shipping mineral materials from the Mountain-Pacific territorial area (including Denver, CO) to any of the five territorial areas within the continental United States. This information is valid as of January, 1984.

AVERAGE SHIPPING COSTS FOR MINERAL MATERIALS, cents per metric ton-kilometer

Material shipped from Mountain-Pacific area	Area destination					
	Mountain-Pacific	Western	South-western	Southern	Official	U.S. average
Metallic ores	2.53	1.04[e]	2.87[e]	NA	NA	2.33
Iron concentrates	1.47	1.04[e]	NA	NA	NA	1.47
Copper precipitates	3.01	NA	NA	NA	NA	3.01
Bauxite ore	2.65	NA	2.91[e]	NA	NA	2.67
Alumina calcine	2.66	NA	2.87[e]	NA	NA	2.66
Nonmetallic minerals[1]	2.94	1.55	2.18	1.96	2.02	2.68
Crushed stone	4.13	NA	NA	NA	NA	4.11
Sand or gravel	2.73	4.75	NA	NA	NA	2.74
Industrial sand	2.54	1.01[e]	1.68[e]	NA	NA	2.54
Refractories	1.83	NA	NA	1.89	NA	1.85
Clay minerals	2.94	NA	NA	1.89	NA	2.37
Fertilizer minerals	3.47	2.65	1.49	2.05	2.25	2.09
Borate, crude	3.39	2.85	NA	1.89	NA	2.67
Sulfur	3.82	3.09	1.99	2.12	2.62	2.34
Gypsum crude	3.30	NA	NA	NA	NA	3.30
Diatomaceous earth	4.31	2.03	2.05	2.31	2.32	2.22
Nonmetallic minerals n.e.c.[2]	2.35	1.84	1.49	1.58	1.47	1.63
Coal	1.87	1.25	1.13	1.30	1.33	1.26

[e]Estimated. NA Not available.

[1]Most nonmetallic ores, except fuels.

[2]Includes agate, crude chalk, lithium, earth or soil, coral, rubidium, graphite, sericite, nepheline syenite, shale, well drilling cores, crude topaz, vermiculite-unexpanded, slag, perlite, cornwall, crystal quartz rock, quartzite, silaceous fluxing ore, silica rock, and zeolites.

Source: 1983 Carload Waybill Sample data collected by Dep. of Transportation, Federal Federal Railroad Administration, Office of Conrail.

Costs for shipping certain mineral materials from the Mountain-Pacific area to other areas may be not available for two reasons; first, shipments of these materials have dropped dramatically during the last 10 yr, making evaluation of costs impossible. Second, certain mineral materials are typically not shipped between two areas. For example, copper precipitates traditionally are never shipped out of the Mountain-Pacific area.

To determine the total cost of transporting a specific mineral material, first select the appropriate cost from the tabulation, then multiply that value by the distance in kilometers the material is to be shipped, and also by the metric tonnage to be shipped. Finally, divide the answer by 100 to get a value in dollars.

Example: The cost for shipping 100,000 mt of fertilizer minerals from Denver, CO, to a point in the Southern Area, 2,500 km, away is:

$$[(2.05¢/\text{mt}\cdot\text{km})\text{x}(100{,}000\text{mt})\text{x}(2{,}500\text{km})/(100¢/\$) = \$5{,}125{,}000.$$

To estimate the cost for shipping mineral materials from one point to another, irrespective of territorial zones, use the following equation:

$$Y = [15.359(D)^{-0.275}]/100$$

where D = distance the material is to be shipped, in kilometers,
and Y = cost, in cents per metric ton kilometer.

The resultant answer must be multiplied by the tonnage and the distance it is to be hauled to get a total cost in dollars.

The following map shows the boundaries for the different territorial areas.


WESTERN
OFFICAL
MOUNTAIN-PACIFIC
SOUTHERN
SOUTHWESTERN

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.4. TRANSPORTATION

9.1.4.5. LONG DISTANCE SURFACE CONVEYOR

These curves cover the cost of transporting material from the mine via a single-flight conveyor belt reinforced with high-strength steel and cover a capacity range of 15,000 to 150,000 mtpd. The material is conveyed up a 10° slope for a distance of 1 km. The conveyor availability is 94%. Usually, the material is crushed or screened at the mine site before being conveyed. Screen and crusher costs are not included in this cost but are covered in separate sections.

The total cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a production rate (X), in metric tons material transported per day. The curves are valid for operations between 15,000 and 150,000 mtpd, operating three shifts per day. The curves include all daily operating and maintenance costs associated with the conveyor operation.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 7.429(X)^{0.464}$
The operating labor costs are distributed as follows:

	Small (15 to 50,000 mtpd)	Large (50,000 to 150,000 mtpd)
Direct labor...............	71%	47%
Maintenance labor..........	29%	53%

The direct labor costs consist of the following typical range of personnel:

	Small (15 to 50,000 mtpd)	Large (50,000 to 150,000 mtpd)	Average salary per hour (base rate)
Operator..................	64%	54%	$16.25
Assistant operator........	36%	46%	13.97

The average wage for labor is $15.32 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 0.068(X)^{0.933}$
The supply cost consists of 100% electric power.

(E) Equipment Operating Cost $(Y_E) = 2.226(X)^{0.358}$
The equipment operating cost consists of 95% for repair parts and 5% for lubrication for the idlers and mechanical parts.

ADJUSTMENT FACTORS

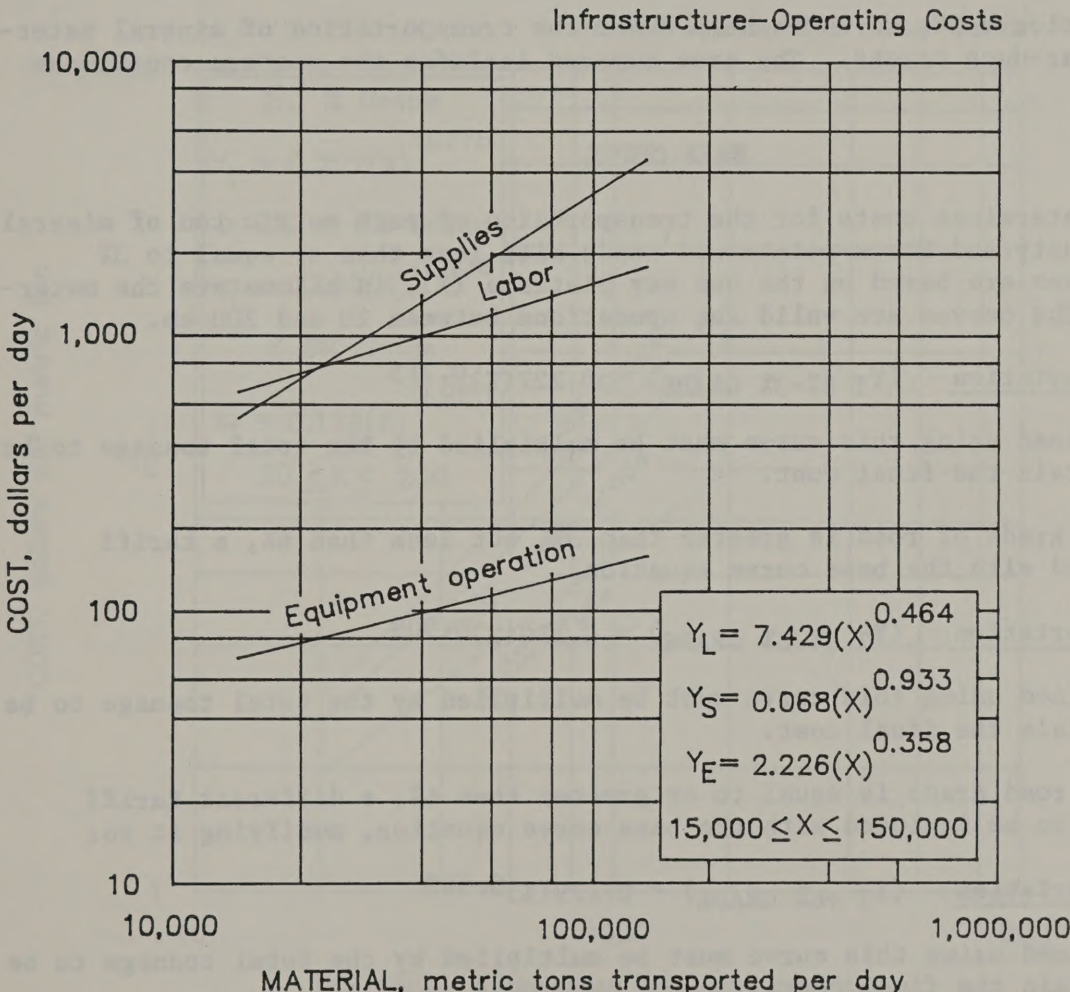
Length and Slope Factor To determine costs for varying conveyor lengths and slopes, multiply the costs obtained from the curves by the following factors:

Labor factor $(F_L) = 0.815+0.190(L)$

Supply factor $(F_S) = [0.208+0.0794(S)][(L/1)]$

Equipment operation factor $(F_E) = L/1$
where L = length of conveyor, in kilometers,
and S = slope of conveyor, in degrees (S is between 0^o and 15^o).

The cost for a decline conveyor is equal to that for a horizontal conveyor (0^o slope).



9.1.4.5. Long distance surface conveyor

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.4. TRANSPORTATION

9.1.4.6. LONG-DISTANCE TRUCK HAULAGE

The trucking industry has undergone intensive change since its recent deregulation. Truck transportation of mineral materials has shifted predominantly away from the class rate system to the bulk commodity method. This has corresponded with a decrease in the number of carriers and an increase in competition. Each carrier now determines his own rate and tariff schedules.

Truck transportation costs as shown here cover the transportation of mineral materials by 23 mt rear-dump trucks. The area covered includes the western contiguous United States.

BASE CURVE

The base curve determines costs for the transportaion of each metric ton of mineral materials via county and State-maintained roads with less than or equal to 3% grades. The curves are based on the one way distance (X), in kilometers the material is hauled. The curves are valid for operations between 20 and 200 km.

(T) Truck transportation $(Y_{T\ 0\%-3\%\ GRADE}) = 0.227(X)^{0.715}$

Costs determined using this curve must be multiplied by the total tonnage to be hauled to obtain the final cost.

When the average grade of road is greater than 3%, but less than 6%, a tariff factor is included with the base curve equation.

(T) Truck transportation $(Y_{T\ 3\%-6\%\ GRADE}) = 0.180(X)^{0.909}$

Costs determined using this curve must be multiplied by the total tonnage to be hauled to obtain the final cost.

When the average road grade is equal to or greater than 6%, a different tariff factor will have to be included with the base curve equation, modifying it to:

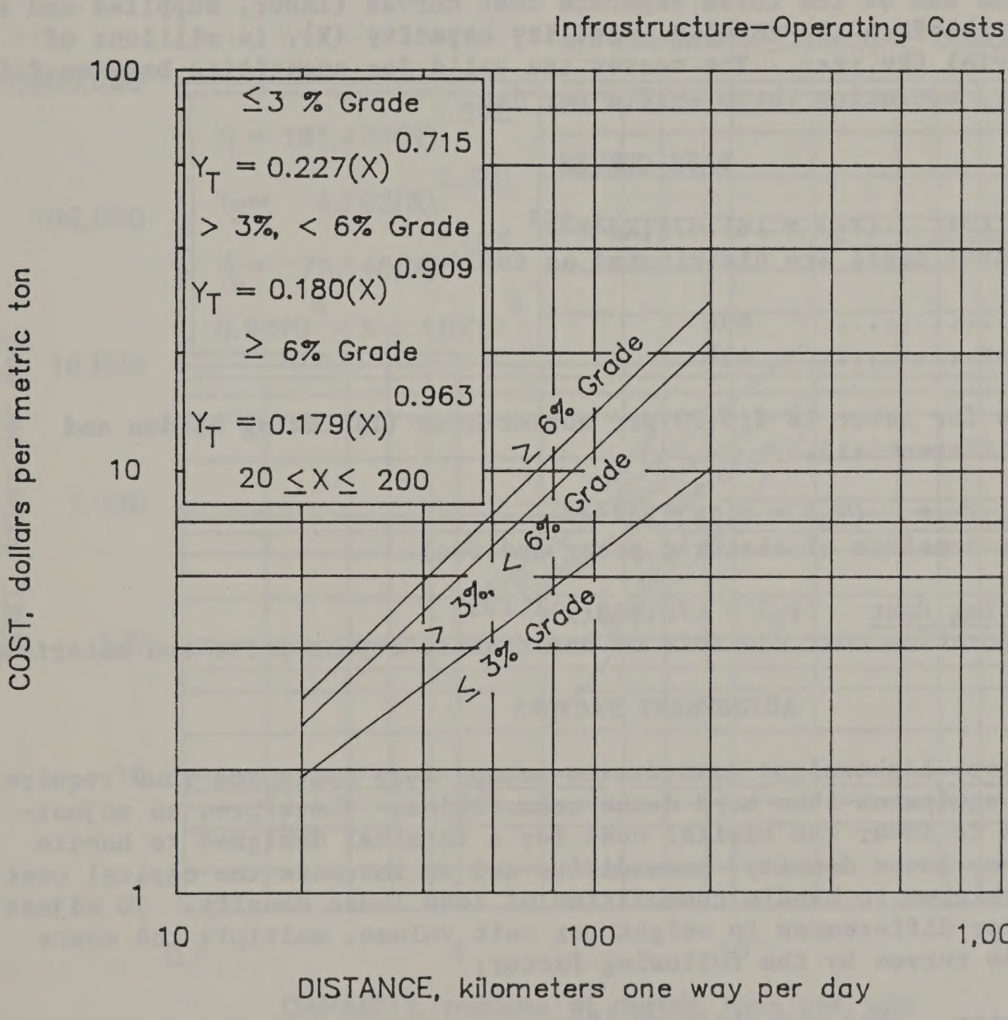
(T) Truck transportation $(Y_{T\ +6\%\ GRADE}) = 0.179(X)^{0.963}$

Costs determined using this curve must be multiplied by the total tonnage to be hauled to obtain the final cost.

ADJUSTMENT FACTORS

Long Term Contract The final values arrived at through multiplying the tonnage by any of the three curves can be reduced by 10% to 20% if long term hauling contracts are to be used.

Tonnage If trucks with carrying capacities greater or less than 23 mt are used, the cost per metric ton should be modified accordingly.



9.1.4.6. Long distance truck haulage

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.4. TRANSPORTATION

9.1.4.7. MARINE TERMINAL

Costs derived from these curves apply to the operation of a deep-water, export, bulk ore marine terminal. Operation cost does not reflect actual terminal charges, but actual costs for railcar or barge receiving, open storage (approximately 10% of the annual throughput), reclaiming, and shiploading.

The total cost is the sum of the three separate cost curves (labor, supplies and equipment operation) based on the terminal facility capacity (X), in millions of metric tons of material per year. The curves are valid for capacities between 0.9 and 16 million mt/yr, operating three shifts per day.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 161.474(X)^{1.558}$
The operating labor costs are distributed as follows:

Direct labor...............	60%
Maintenance labor..........	40%

The average wage for labor is $15.78 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 4.792(X)^{2.301}$
The supply curve consists of electric power and fuel.

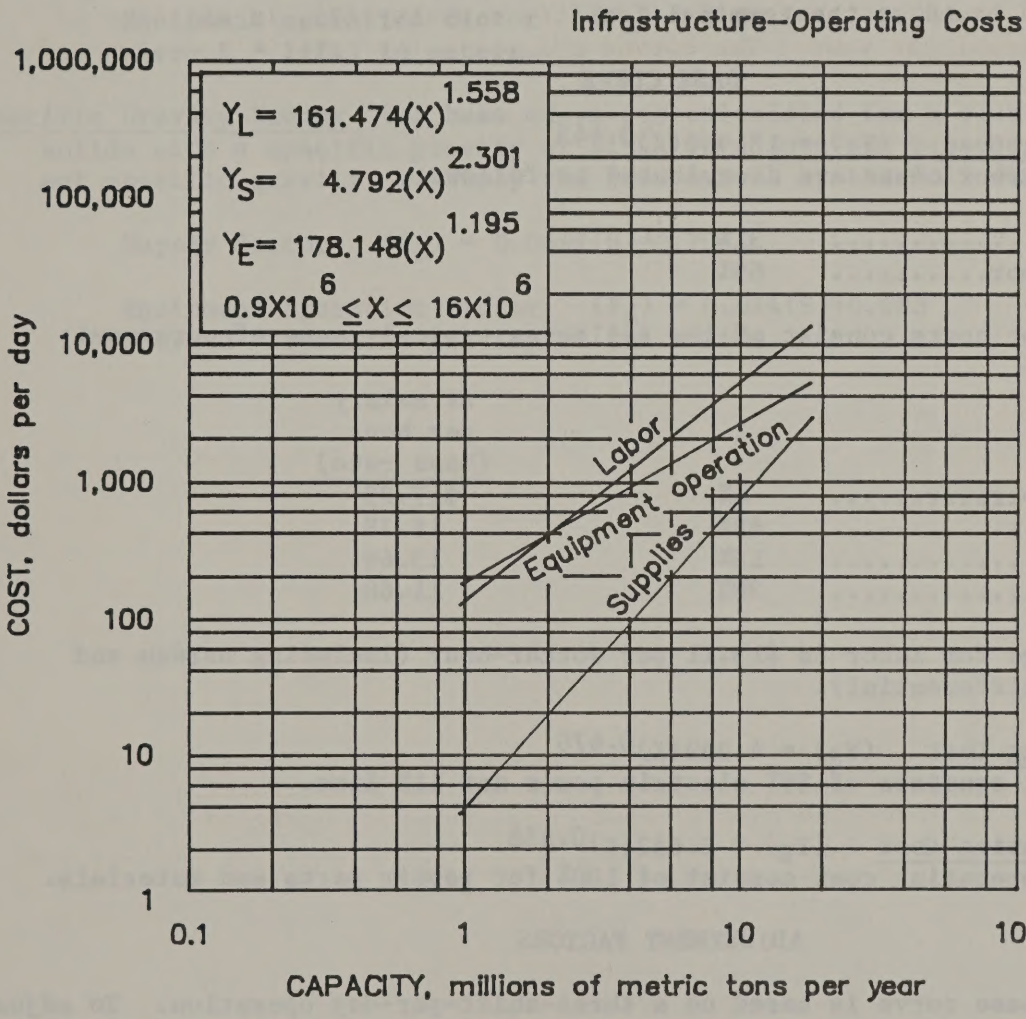
(E) Equipment Operating Cost $(Y_E) = 178.148(X)^{1.195}$
The equipment operating cost consists of maintenance repair parts and materials.

ADJUSTMENT FACTORS

Density (Loose) Factor Lightweight commodities occupy more space and thus require larger handling equipment than more dense commodities. Therefore, an adjustment is required to lower the capital cost for a terminal designed to handle more dense (higher loose density) commodities and to increase the capital cost of a terminal designed to handle commodities of less loose density. To adjust the base curve for differences in weight per unit volume, multiply the costs obtained from the curves by the following factor:

Density factor $(Y_D) = 3.418(D)^{-0.167}$
where D = loose density, in kilograms per cubic meter.

See table A-2 for loose densities.



9.1.4.7. Marine terminal

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.4. TRANSPORTATION

9.1.4.8. SLURRY PIPELINE

The operating cost curves for slurry pipeline cover the cost of transporting a slurry. The base curves are based on a slurry pipeline of 10 km in length with a lift of 150 m pumping solids at specific gravity of 4.3. The total cost is the sum of the three separate cost curves (labor, supplies, and equipment operation) at an adjusted feed rate (X), in metric tons material transported per day. The curves are valid for operations between 900 and 32,000 mtpd, operating three shifts per day.

BASE CURVE

(L) Labor Operating Cost $(Y_L) = 13.940(X)^{0.445}$
The operating labor costs are distributed as follows:

Direct labor...............	31%
Maintenance labor..........	69%

The direct labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Control Room Operator......	6%	$17.23
Mill Operator..............	49%	16.78
Mill Helper................	15%	13.66
Mill Laborer...............	30%	11.68

The average wage for labor is $15.11 per worker-hour (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 4.259(X)^{0.676}$
The supply cost consists of 89% electric power and 11% lime.

(E) Equipment Operating Cost $(Y_E) = 3.652(X)^{0.458}$
The equipment operating cost consist of 100% for repair parts and materials.

ADJUSTMENT FACTORS

Shift Factor The base curve is based on a three-shift-per-day operation. To adjust for a different number of shifts, calculate the shift factor by dividing the base number of shifts (three) by the actual number of shifts.

Slurry Pipeline Length The base curve was calculated for a slurry pipeline of 10 km in length. To adjust for different slurry pipeline lengths, multiply the base curves by the following factors:

Labor factor $(F_L) = 0.0026(P)+0.974$

Supply factor $(F_S) = 0.0172(P)+0.828$

Equipment operation factor $(F_E) = 0.011(P)+0.890$
where P = pipeline length, in kilometers.

Slurry Pipeline Lift Factor The base curve was calculated for a slurry pipeline with a lift of 150 m. To adjust for different slurry pipeline lifts, multiply the base curves by the following factors:

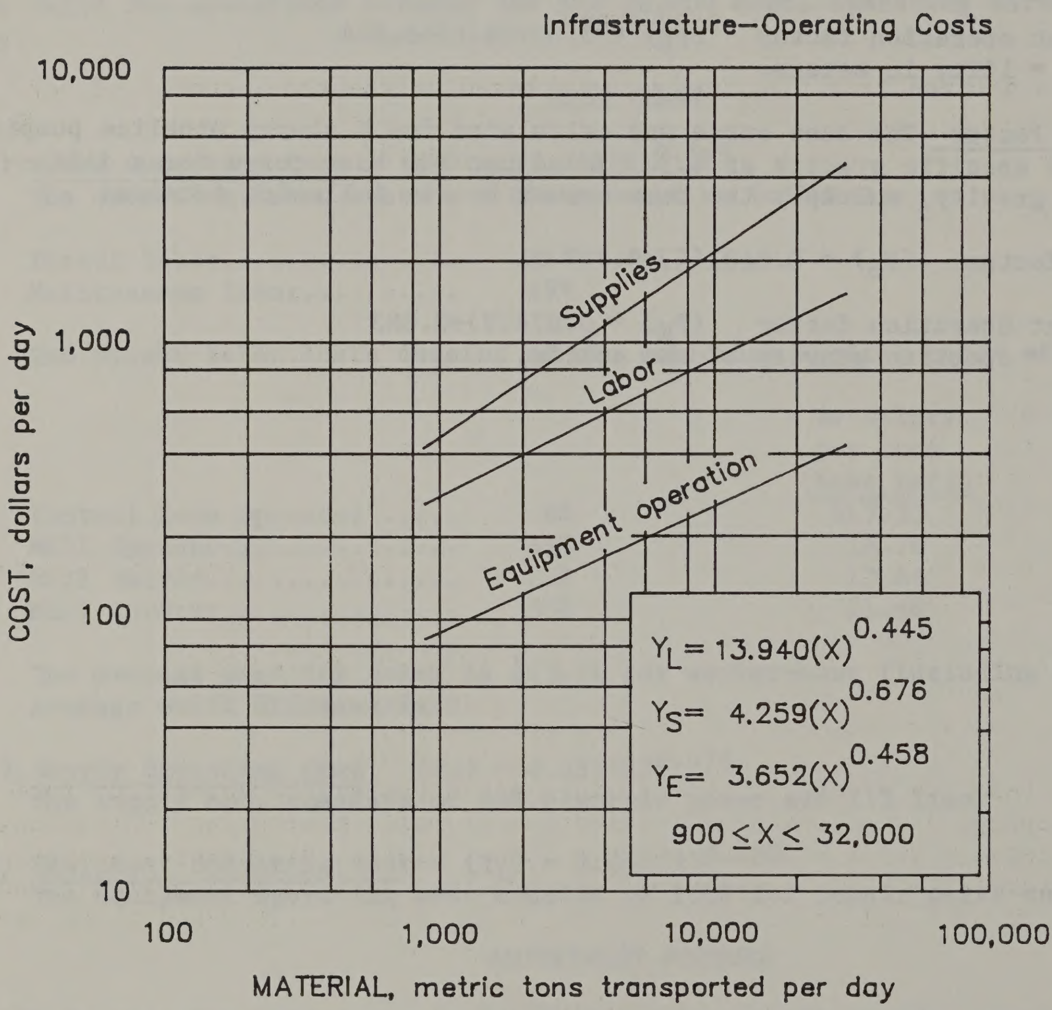
Supply factor $(F_S) = 0.00163(L)+0.755$

Equipment operation factor $(F_E) = 0.00104(L)+0.844$
where L = lift, in meters.

Specific Gravity Factor The base curve was calculated for a slurry pipeline pumping solids with a specific gravity of 4.3. To adjust the base curve for a different specific gravity, multiply the base curves by the following factors:

Supply factor $(F_S) = 0.0681(S)+0.707$

Equipment operation factor $(F_E) = 0.074(S)+0.683$
where S = specific gravity of the solids.



9.1.4.8. Slurry pipeline

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.5. TOWNSITE-CAMPSITE

CAMPSITE

Where conditions such as remote location or seasonal operation require a single-status campsite (i.e., room, board, and recreation facility), the daily operating cost should be derived from the following base cost curve. Today a caterer is usually employed to provide board, housekeeping, and recreation supervision. Heat, lights, garbage disposal, and plant maintenance are usually provided by the owner.

BASE CURVE

The total cost is derived from the supply curve based on the total number of persons who occupy the campsite (X). The curve is valid for campsites occupied by 20 to 1,000 persons. All persons recieve both room and board.

(S) Supply Operating Cost $(Y_S) = 37.143(X)^{0.897}$

	Small (20 to 450 persons)	Large (450 to 1,000 persons)
Board..........................	61.5%	59.0%
Housekeeping and recreation...	23.9%	23.0%
Heat..........................	6.4%	9.0%
Light..........................	2.4%	3.4%
Maintenance...................	5.8%	5.6%

If the number of persons requiring board varies from the number of persons requiring room, use the following equation:

(S) Supply Operating Cost $(Y_S) = [37.143(X)^{0.897}][0.60(B/R)+0.40(R)]$
where B = number of persons requiring board only,
and R = number of persons requiring room only.

These curves are based on a caterer who provides all necessary personnel for food service, housekeeping, distribution and collection of mail, monitoring recreation, etc., and all necessary supplies, such as pots, pans, dishes, silverware, sheets, pillow cases, blankets, waste cans, recreation supplies, janitorial supplies, food, etc. The evaluator must add the cost for local, state, or federal taxes where required.

ADJUSTMENT FACTORS

Owner-Operator Factor When the facility is owner-operated rather than catered, multiply the cost obtained from the curve by the following factor:

Owner-operator factor $(F_O) = 0.93$

Diesel Power Factor When the electric power is provided by a diesel-electric system rather than a power line grid, multiply the cost obtained from the curve by the following factor:

Diesel power factor $(F_D) = 1.04$

TRAILER COURT

Where conditions such as remote location or lack of available housing require installation of a family trailer court complete with utilities, laundromat, recreation facilities, blacktop driveway, and possibly swimming pool, the daily operating cost should be derived from the following two curves. The total cost is derived from the supply curve, based on the total number of trailer spaces, (X), required. The curve is valid for trailer courts with 20 to 1,000 units.

BASE CURVE

The curves are based on trailer and facility maintenance, insurance, casualty insurance, supervisory and worker wages, plus overhead, heat, and lights.

(S) Supply Operating Cost $(Y_{S\ FREE}) = 49.514(X)^{0.590}$
Company-owned mobile homes, spaces, and facilities where the trailers and spaces are free to supervisors and workers. The company pays all operating costs on the facility.

(S) Supply Operating Cost $(Y_{S\ RENTED}) = 1,676.049(X)^{-0.716}$
Company-owned mobile homes, spaces, and facilities where the trailers and spaces are rented to supervisors and workers. The company pays for any loss on the facility.

ADJUSTMENT FACTORS

Swimming Pool Factor When the trailer court does not provide a swimming pool, multiply the curve $(Y_{S\ FREE})$ by the following factor:

Swimming pool factor $(F_{P\ FREE}) = 0.82$

When the spaces and trailers are rented and the trailer court has 52 or more units it will show a profit. If there are less than 52 units multiply the curve $(Y_{S\ RENTED})$ by the following factor:

Swimming pool factor $(F_{P\ RENTED}) = 0.05$

Trailer Space Rental Factor When the occupants rent trailer space for their own trailers, multiply the curve $(Y_{S\ FREE})$ by the following factor:

Trailer space rental factor $(F_{R\ FREE}) = 0.36$

PERMANENT HOUSING

Company totally owned and operated townsites are decreasing in number because of their high cost and persistent social problems. The trend seem to be toward small family housing facilities combined with an existing nearby city.

Large townsite permanent housing

Today, the military appears to be the greatest user of this type of facility. The Air Force provides housing to its officers and enlisted personnel. The Government pays for housing and facility maintenance, all utilities, supervisor, and worker labor, etc. The average operating costs for 1983 were:

McCord Air Base--993 units $6.66 per day per unit
Fairchild Air Base--1,580 units $6.93 per day per unit

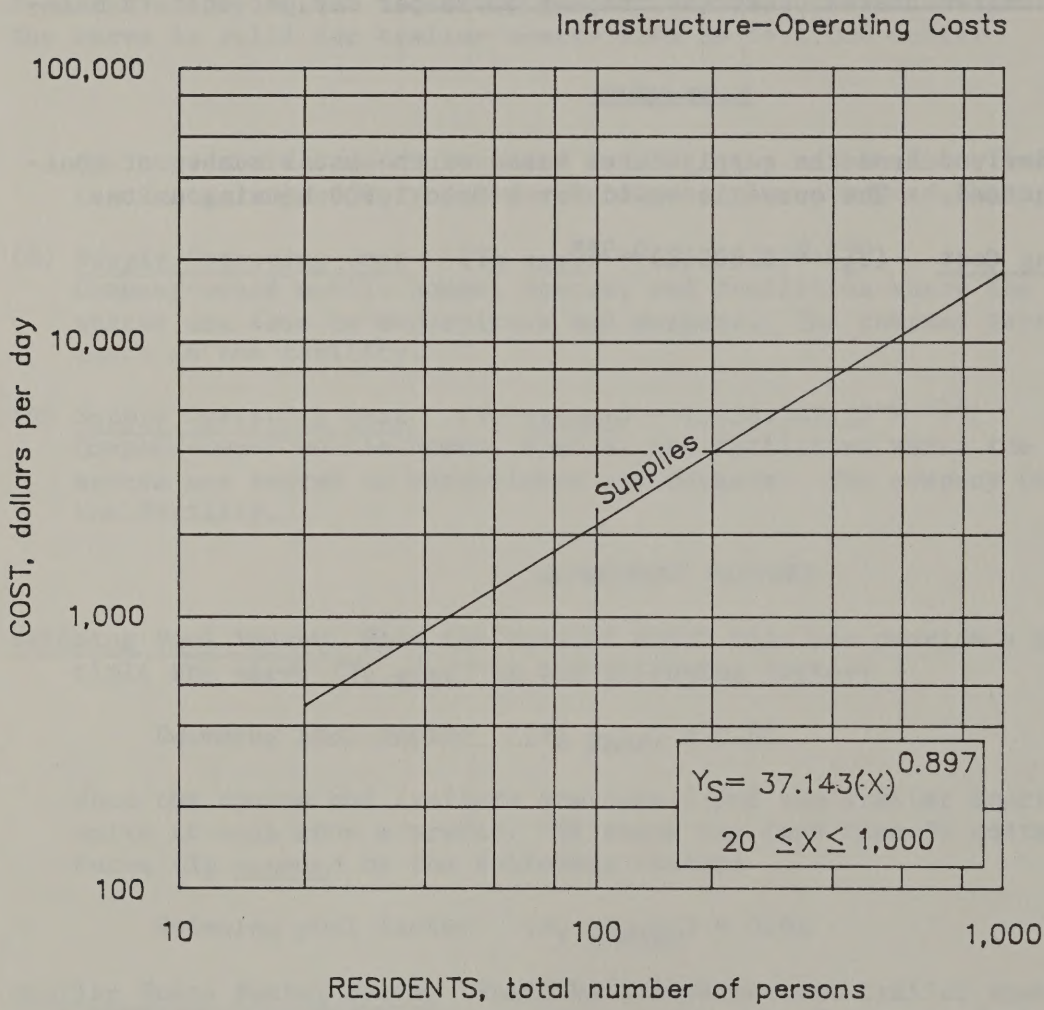
Small townsite permanent housing

These facilities are generally rented to their occupants at a modest fee with the company paying for the general maintenance, insurance, and taxes. Rent is applied to the capital investment. A new housing facility (175 family units) in the western United States, cost the company $0.98 per day per unit to maintain.

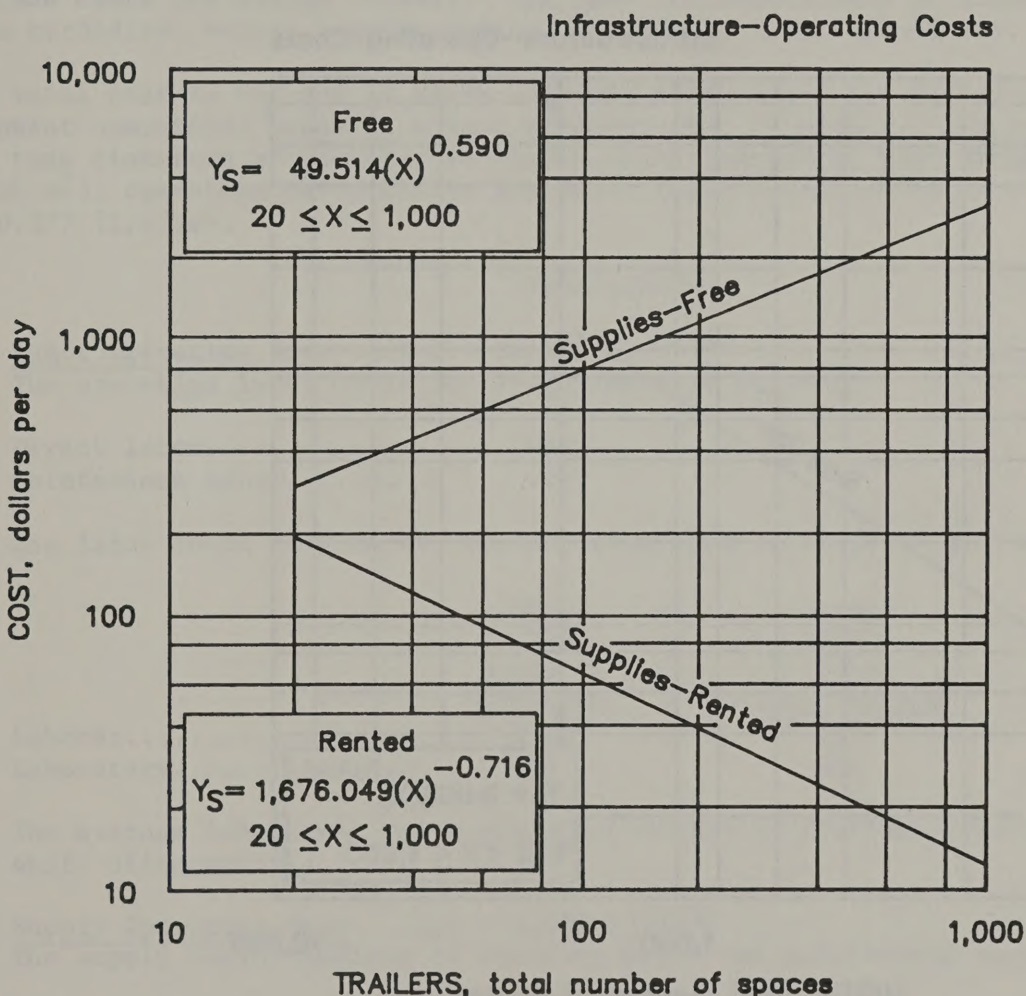
BASE CURVE

The total cost is derived from the supply curve based on the total number of housing units, (X), required. The curve is valid for 140 to 1,900 housing units.

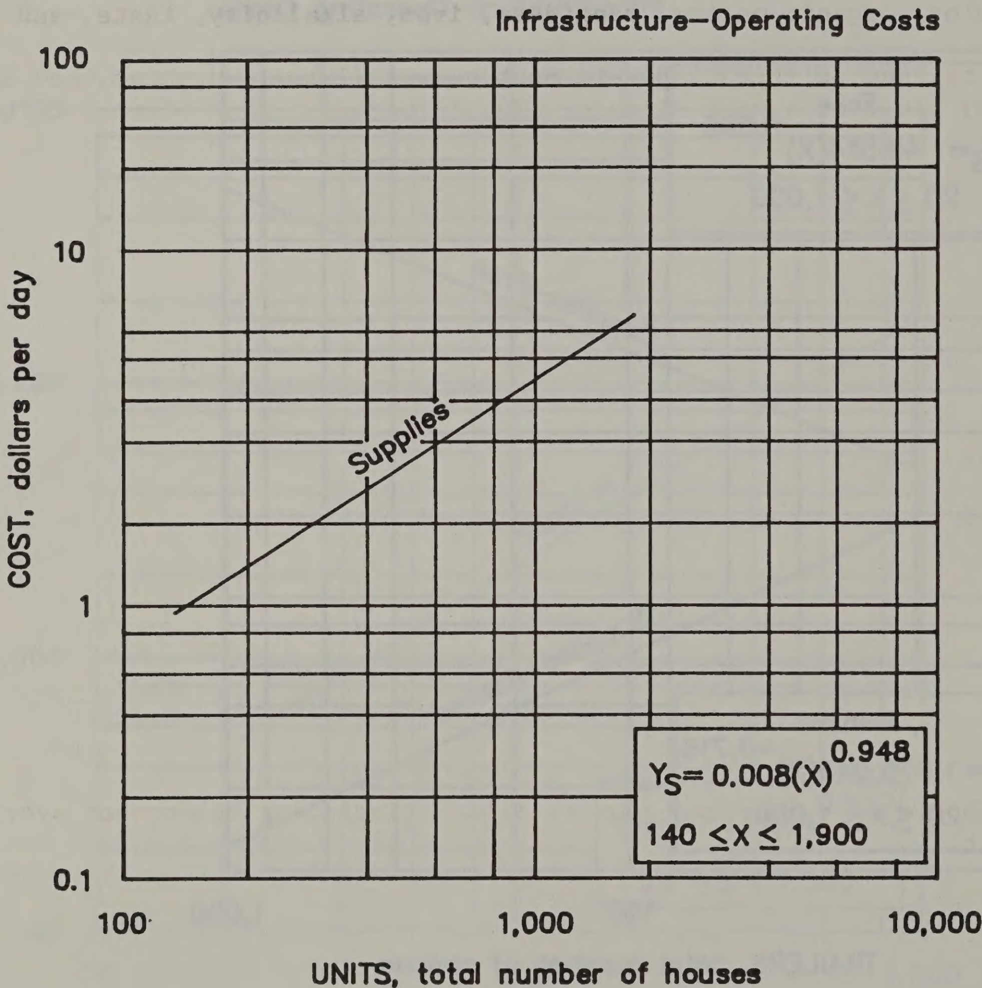
(S) <u>Supply Operating Cost</u> $(Y_S) = 0.008(X)^{0.948}$



9.1.5.a Townsite-Campsite
CAMPSITE



9.1.5.b Townsite-Campsite
TRAILER COURT



9.1.5.c Townsite-Campsite
PERMANENT HOUSING

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.6. WASTEWATER TREATMENT

9.1.6.1. CLARIFICATION

This operation is a solids-contact clarifier used for water clarification by precipitation and/or coagulation. This cost curve is intended to remove suspended solids formed after final neutralization of out-of-pipe effluent. The curves include all principal costs associated with the operation of the unit. It does not include costs for sludge removal. The unit can selectively or simultaneously remove turbidity, color, organic matter, manganese, iron, alkalinity, taste, and odor.

The total cost is the sum of three separate cost curves (labor, supplies, and equipment operation) based on a tank diameter (X), in meters. The curves are valid for tank diameters between 2.7 to 46.0 m (cross-sectional area ranging from 5.72 to 1,661 m^2), operating three shifts per day. Costs are based on an overflow rate of 0.377 (L/s)/m^2.

BASE CURVES

(L) Labor Operating Cost $(Y_L) = 38.931(X)^{0.119}$
The operating labor costs are distributed as follows:

Direct labor...............	100%
Maintenance labor..........	0%

The labor costs consist of the following typical range of personnel:

	Small Dia (5.72 to 75 meters)	Large Dia (75 to 1,661 meters)	Av salary per hour (base rate)
Laborer....................	60%	54%	$13.66
Laboratory.................	40%	46%	15.89

The average labor cost per worker-hour is $14.43 (including burden and average shift differential).

(S) Supply Operating Cost $(Y_S) = 1.083(X)^{0.633}$
The supply curve consists of electric power and maintenance supplies.

	Small Dia (5.72 to 75 meters)	Large Dia (75 to 1,661 meters)
Electric...................	60%	34%
Maintenance................	40%	66%

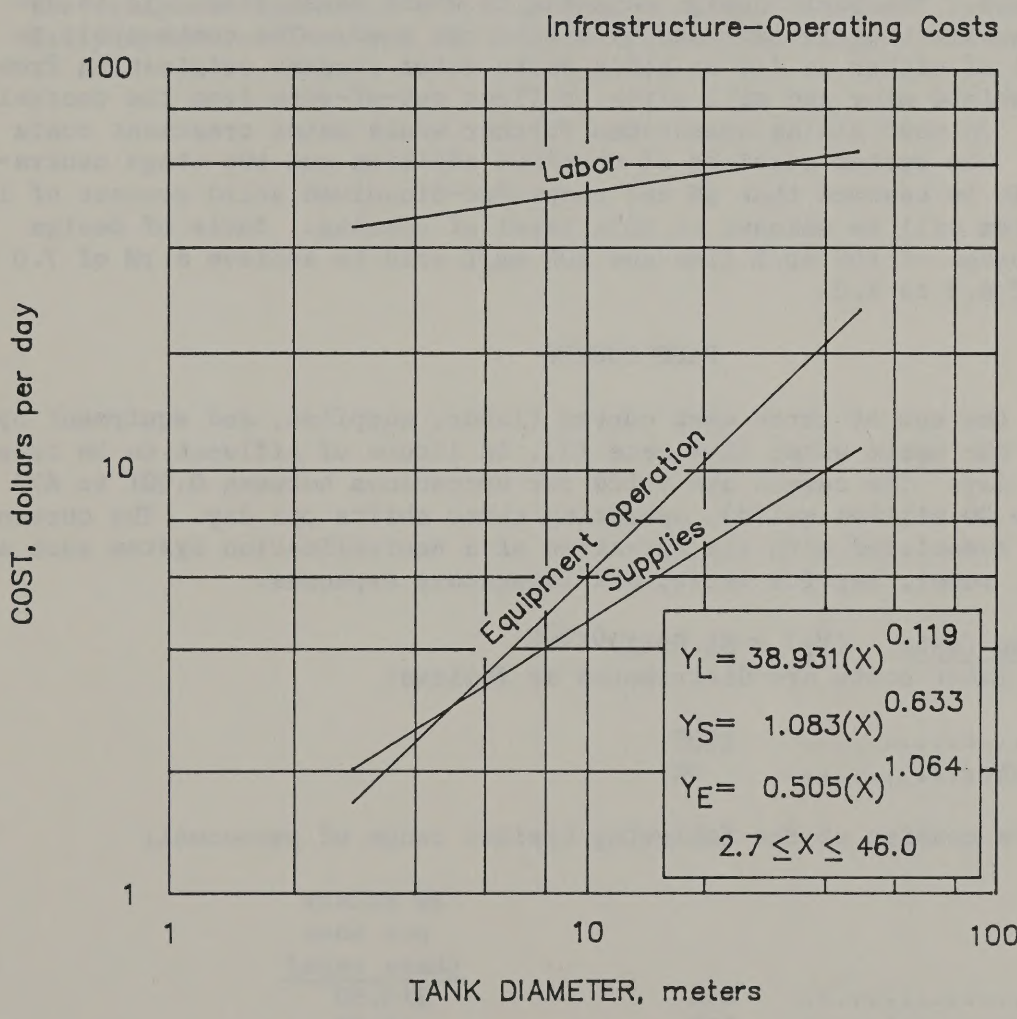
(E) Equipment Operating Cost $(Y_E) = 0.505(X)^{1.064}$
The equipment operating cost consists of 100% for repair parts and covers the daily operation cost for all clarification equipment.

ADJUSTMENT FACTORS

Flocculant Factor Normally, additional flocculants are not needed in the mine waste water treatment after neutralization. However, if polymers are needed or used, add the following factor to the supply cost obtained from the curve:

Supply factor $(F_S) = 0.334(D)^{1.812}$
where D = clarifier tank diameter, in meters.

The polymer is based on a standard dosage of 1.5 mg/L influent and an average polymer cost of $2.10/lb.



9.1.6.1. Wastewater treatment
CLARIFICATION

9.1. INFRASTRUCTURE--OPERATING COSTS

9.1.6. WASTE WATER TREATMENT

9.1.6.2. NEUTRALIZATION

The Environmental Protection Agency's publication EPA-600/2-82-00/d "Treatability Manual, Vol. IV, Cost Estimating," April 1983, was the source of cost development. One is referred to this manual if further detail in neutralization costs is needed. Additionally, other waste water treatment methods are costed in this EPA manual.

The operating cost curves are used when neutralization of waste water effluent (out-of-pipe) is required. The basic design variable is waste water flow. It is assumed that flow equalization is provided by a tailings pond. The costs apply to the neutralization of either acidic or basic waste water streams originating from mine, mill, or combined mine and mill after it flows out-of-pipe from the central impoundment pond. In most mining operations further waste water treatment costs are not required. The system consists of chemical addition and two-stage neutralization tanks. It is assumed that pH and suspended-dissolved solid content of influent to the system will be unknown at this level of costing. Basis of design uses a standard dosage of 100 mg/L lime and 100 mg/L acid to achieve a pH of 7.0 over a pH range of 6.5 to 8.0.

BASE CURVES

The total cost is the sum of three cost curves (labor, supplies, and equipment operation) based on the waste water flow rate (X), in liters of effluent to be treated per second per day. The curves are valid for operations between 0.001 to 876 L/s (22.8 gal/d to 20 million gal/d), operating three shifts per day. The curves include all costs associated with the operation of a neutralization system such as labor, lime, acid, power, service water, and laboratory expenses.

(L) <u>Labor Operating Costs</u> $(Y_L) = 84.85(X)^{0.000}$

The operating labor costs are distributed as follows:

Direct labor...............	100%
Maintenance labor..........	0%

The labor costs consist of the following typical range of personnel:

		Av salary per hour (base rate)
Laborer....................	89%	$15.80
Laboratory.................	11%	15.80

The average labor cost per worker-hour is $15.80 (including burden and average shift differential).

(S) <u>Supply Operating Costs</u> $(Y_{S\ 0.001-8.76\ L/s\ RATE}) = 24.13(X)^{0.950}$

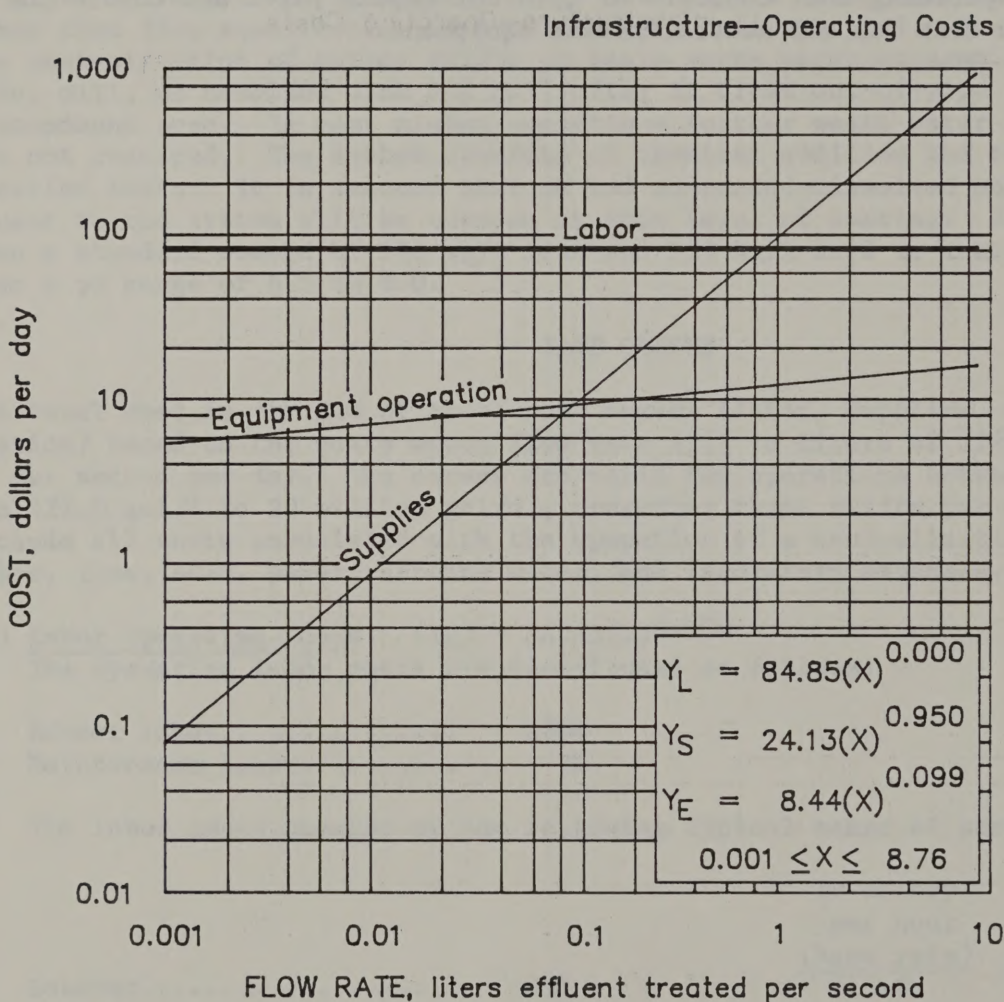
$(Y_{S\ 8.76-876\ L/s\ RATE}) = 21.282(X)^{0.997}$

The supply costs consists of electric power, water, and chemicals and lime in the following proportions:

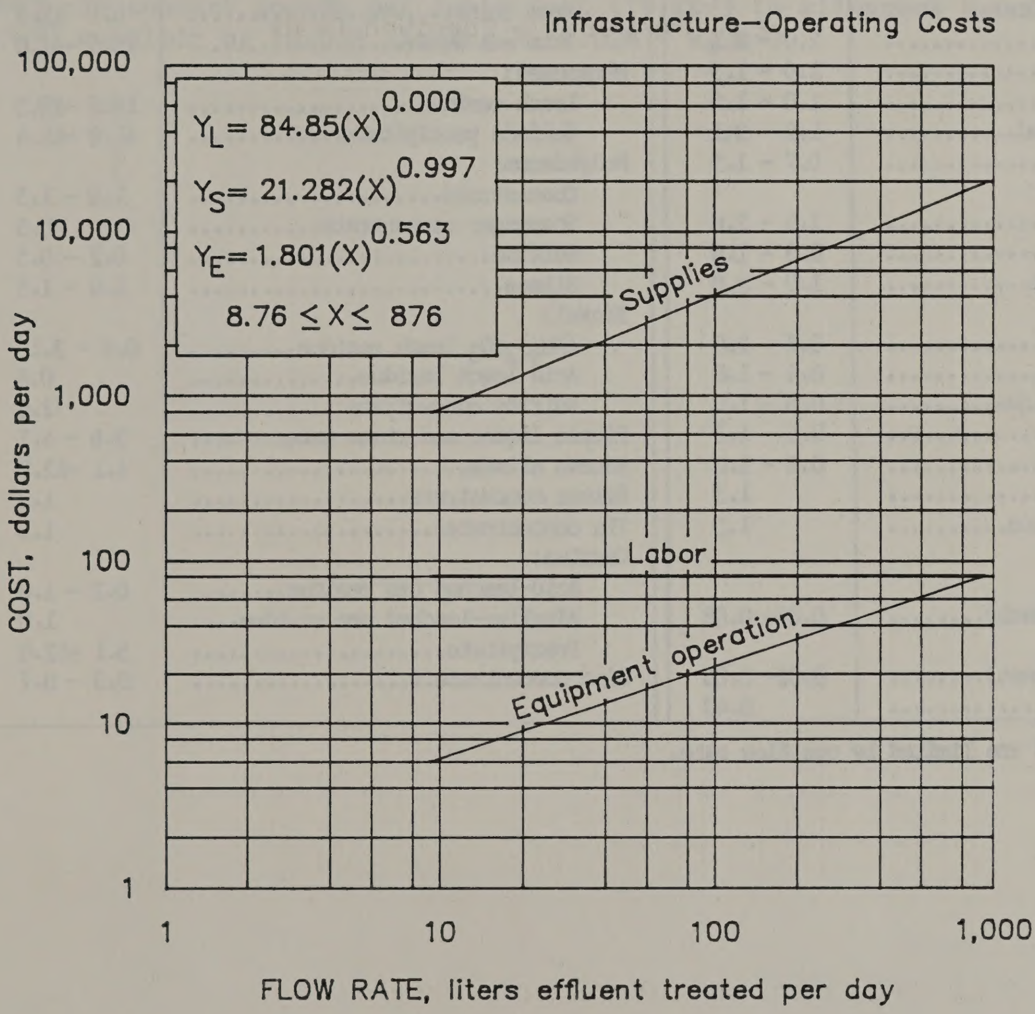
	Small (0.001 to 8.76 L/s)	Large (8.76 to 876 L/s)
Electric power.............	3%	2%
Water......................	80%	89%
Chemicals and lime.........	17%	9%

(E) Equipment Operating Costs $(Y_{E\ 0.001\text{-}8.76\ L/s\ RATE}) = 8.44(X)^{0.099}$
$(Y_{E\ 8.76\text{-}876\ L/s\ RATE}) = 1.801(X)^{0.563}$

The equipment operating cost consists of 100% for repair parts and covers the daily operation cost for all neutralization equipment.



9.1.6.2.a Wastewater treatment
NEUTRALIZATION



9.1.6.2.b Wastewater treatment
NEUTRALIZATION

APPENDIX.—REFERENCE TABLES

Table A-1 - Thickener applications

Thickener application	Unit area, m^2/mtpd	Thickener application	Unit area, m^2/mtpd
Alumina, Bayer process:		Lead concentrates..................	0.7 - 1.8
Red mud monohydrate ore:		Lime mud:	
Primary....................	5.1 - 6.7	Acetylene generator............	1.5 - 3.4
Secondary..................	3.1 - 4.1	Lime-soda process..............	1.5 - 2.6
Other washing..............	2.0 - 3.1	Magnesium hydroxide:	
Red mud trihydrate ore:		From brine.....................	6.1 -10.2
Primary....................	2.0 - 3.1	From sea water.................	20.5 -41.0
Washers....................	1.0 - 1.5	Manganese:	
Final......................	1.0 - 1.5	Leach residue..................	10.2 -20.5
Hydrate, fine or seed..........	1.2 - 3.1	Sulfide precipitate............	41.0 -61.4
Asbestos.......................	0.7 - 1.5	Molybdenum:	
Cement:		Concentrate....................	1.0 - 1.5
Wet process....................	1.5 - 2.6	Scavenger concentrate..........	0.5
Kiln dust......................	0.3 - 1.8	Sulfide........................	0.2 - 0.5
Cobalt-nickel sulfides.........	1.0 - 2.0	Slimes.........................	1.0 - 1.5
Copper:		Nickel:	
Concentrate....................	0.2 - 2.0	$(NH_4)_2CO_3$ leach residue.........	0.5 - 3.1
Tailings.......................	0.4 - 1.0	Acid leach residue.............	0.8
$(NH_4)_2CO_3$ leach residue.........	0.5 - 1.0	Sulfide concentrate............	2.6
Cyanide slimes.................	0.5 - 1.3	Pickle liquor and rinse water.......	3.6 - 5.1
Flue dust, power plant.........	0.2 - 1.0	Potash slimes..................	4.1 -12.8
Gold tellurides................	1.3	Silver concentrate.............	1.3
Heavy media ferrosilicon.......	1.3	Tin concentrate................	1.3
Iron ore:		Uranium:	
Fine concentrate		Acid-leached ore residue........	0.2 - 1.0
(65%-90%, -325 mesh)........	0.04- 0.08	Alkaline-leached ore residue....	1.0
Coarse concentrate		Precipitate....................	5.1 -12.8
(45%-65%, -325 mesh)........	0.02- 0.05	Zinc concentrate...............	0.3 - 0.7
Tailings[1].....................	0.43		

[1]Hematites at 20% feed are limited by overflow rate.

Table A-2 - Loose density factors

Commodity	kg/m^3	lb/ft^3	Factor	Commodity	kg/m^3	lb/ft^3	Factor
Phosphate......	753	47	1.12	Copper Ore[1]...	1,859	116	0.96
Coal...........	801	50	1.10	Iron Ore			
Bauxite........	1,314	82	1.02	30% Fe......	2,052	128	0.95
Limestone......	1,554	97	1.00	50% Fe......	2,340	146	0.93
Dolomite.......	1,554	97	1.00	60% Fe......	2,597	162	0.90
Granite........	1,603	100	0.99				

[1]sulphides up to 10% Cu

NOTE--To convert pounds per cubic foot (lb/ft^3) to kilograms per cubic meter (kg/m^3) multiply by 16.028 ($lb/ft^3 \times 16.028 = kg/m^3$).

Table A-3. - Major slurry pipelines and their characteristics

Material	Pump Type	Length, km	Diam., mm	Velocity, m/sec	Pressure, kg/cm^2	S.G.	Particle Size, mm	% Solids	Flow, L/min
bauxite........	plunger	73	200	2.1	NA	2.3	0.4	55	3,785
beach sand.....	centrifugal	3	508	4.6	21	2.70	2.3	35	52,990
coal...........	piston	174	273	1.5	86	1.40	1.2	52	6,245
	piston	440	457	1.7	126	1.40	2.3	50	17,030
	piston	1,667	965	1.7	NA	1.40	2.3	50	64,350
copper conc....	plunger	27	168	1.7	141	4.3	0.2	65	1,820
	plunger	111	114	1.5	162	4.3	0.15	65	520
	plunger	61	143	1.8	148	4.30	0.15	65	720
gilsonite......	plunger	116	168	1.2	144	1.05	4.7	46	1,250
gold tailings..	centrifugal	11	200	1.4	80	2.7	0.1	45	3,400
gold quartz....	Mars pump	mine hoist	200	1.4	80	2.7	0.6	50	2,200
hematite.......	plunger	403	508	1.7	141	4.9	0.07	60	18,930
	plunger	48	508	1.7	NA	4.9	0.07	60	18,930
iron sands.....	centrifugal	8	219	4.9	33	4.9	0.6	60	8,710
limestone......	piston	27	194	1.8	90	2.70	0.6	60	3,100
	piston	92	273	1.4	148	2.70	0.4	61	3,260
	piston	10	219	1.5	68	2.70	0.3	60	2,350
magnetite......	plunger	86	244	1.7	141	4.9	0.15	60	4,390
	gravity	48	219	1.8	4	4.9	0.10	60	4,160
	plunger	26	273	1.8	1,230	4.9	0.10	60	6,430
	plunger	32	219	1.8	101	4.9	0.07	60	4,160
phosphate......	centrifugal	6	457	4.2	14	3.2	1.2	40	37,850
	plunger	113	244	2.1	1,900	0.3	0.3	65	7,950

NA Not available

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